Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

SHOUT
SHARE
IT

UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
North Dakota Agricultural College

DEPARTMENT BULLETIN No. 1170

Washington, D. C. ▼ July, 1923

EFFECTS OF DIFFERENT SYSTEMS AND INTENSITIES OF GRAZING UPON THE NATIVE VEGETATION AT THE NORTHERN GREAT PLAINS FIELD STATION

By

J. T. SARVIS, Assistant Agronomist, Office of Dry-Land Agriculture Investigations
Bureau of Plant Industry

CONTENTS

	Page
Introduction	1
Plan of the Grazing Experiment	3
Land Used for the Experiment	5
Relation of Precipitation to Native Forage Production	7
Deferred and Rotation System of Grazing	8
Period of Grazing and Cattle Used	10
Weighing the Cattle	11
Gains of the Cattle	12
Percentage of Vegetation Annually Removed by Grazing	15
Measure of Efficiency of a Pasture or System of Grazing	17
Botanical Studies in Connection with the Experiment	19
Other Studies Bearing upon the Experiment	33
Soil Moisture	35
Palatability of the Vegetation	35
Causes of the Deterioration of Native Pastures by Grazing with Cattle	38
Grazing Capacity Based upon the Native Vegetation	39
Salient Points Revealed by the Grazing Experiment	42
Conclusions and Summary	42

WASHINGTON
GOVERNMENT PRINTING OFFICE
1923

UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
North Dakota Agricultural College

DEPARTMENT BULLETIN No. 1170

Washington, D. C. ▼ July, 1923

EFFECTS OF DIFFERENT SYSTEMS AND INTENSITIES OF GRAZING UPON THE NATIVE VEGETATION AT THE NORTHERN GREAT PLAINS FIELD STATION.

By J. T. Sarvis, *Assistant Agronomist, Office of Dry-Land Agriculture Investigations, Bureau of Plant Industry.*

CONTENTS.

	Page.		Page.
Introduction	1	Botanical studies in connection with the experiment	19
Plan of the grazing experiment	3	Other studies bearing upon the experiment	33
Land used for the experiment	5	Soil moisture	35
Relation of precipitation to native forage production	7	Palatability of the vegetation	35
Deferred and rotation system of grazing	8	Causes of the deterioration of native pastures by grazing with cattle	38
Period of grazing and cattle used	10	Grazing capacity based upon the native vegetation	39
Weighing the cattle	11	Salient points revealed by the grazing experiment	42
Gains of the cattle	12	Conclusions and summary	42
Percentage of vegetation annually removed by grazing	15		
Measure of efficiency of a pasture or system of grazing	17		

INTRODUCTION.

During the period when the beef-cattle industry on the free ranges of the Great Plains area was in a thriving condition, meager authentic information was recorded regarding the best utilization of the native vegetation. This information is lacking because there was little demand at that time for the investigation of the subject through a systematic study of grazing problems. The range was looked upon as an inexhaustible supply of forage for all classes of stock. If the range became short in one place, it was only necessary to move to a new area. With the advent of the dry-land farmer and the consequent splitting up of the range, however, grazing became more intensified, and a demand arose for information regarding range and pasture management. The problem was not only how to restore overgrazed areas, but also how to graze an area that was still in a high state of production in order to afford the best utilization of the forage and to maintain the range in good condition. This problem

47606—23——1

is one well worthy of serious consideration and careful experimentation, for the value of the products of pastures greatly exceeds that of many of the important cultivated crops. As it has become necessary to establish experiment stations for the purpose of studying problems of crop production, the need of experiments bearing upon pasture problems has also developed. In one instance the object is to supply information about crops, while in the other it is to give information on range and pasture management. The two problems are intimately related.

The results obtained by the Office of Dry-Land Agriculture Investigations in determining the possibilities and best methods of crop production on the Great Plains early indicated the necessity of livestock production and the utilization of the native grasses as an integral part of the farming system in the greater portion of the area. It was not until the establishment of the field station near Mandan, N. Dak., however, that this phase of the investigations could be undertaken. It was made possible because of the equipment afforded this station and the desire of T. P. Cooper, director, and Prof. J. H. Shepperd, vice director, of the North Dakota Agricultural Experiment Station, to cooperate in this work in their State.

The cooperative grazing experiment at the Northern Great Plains Field Station, near Mandan, N. Dak., was begun in 1915. This experiment is conducted by the Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the North Dakota Agricultural Experiment Station. The office mentioned furnishes the land and equipment and conducts the details of the experiment. The State furnishes the cattle used for grazing and follows them with observations before they are put on the grass in the spring, while they are on the pastures, and after they are removed in the fall. The work of the State includes a study of economic feeding and marketing, shipping, shrinkages, dressing percentages, and other special livestock features.

All the details of the grazing experiment, including the handling and weighing of the cattle, the technical botanical studies, the taking of notes, and the keeping of records are under the immediate supervision of J. T. Sarvis. All notes, records, and results of this experiment are available for publication or other purposes alike to the North Dakota Agricultural Experiment Station and to the United States Department of Agriculture.

The initial purpose of the experiment was to study the effect of different intensities of grazing upon the native vegetation and to note the gains of the cattle. The question of primary importance was considered to be the number of acres of native range required to feed a steer during the grazing season and at the same time enable him to make a reasonable gain in weight. At the beginning of the experiment it seemed that this would be an easy phase of the problem to determine. However, as the experiment progressed, other factors arose which were of equal or superior significance. These are (1) the effects of grazing upon the native vegetation, (2) the extent of gains of the cattle, and (3) the maximum utilization of the vegetation.

In a grazing experiment of this nature it is not only necessary to recognize the species of plants that make up the native vegetation,

but also to determine the effect of grazing upon individual species. One of the first facts observed in studying the grazing of cattle is that they will eat readily some species of plants and will avoid certain other species. This preference of cattle for some plants may largely influence the determination of the best system of grazing. The species that are avoided may be able to increase to the detriment of those readily grazed unless the system of grazing is designed to prevent such an occurrence.

This bulletin is devoted to a study of the influence of different systems and intensities of grazing upon the various species of plants that make up the native vegetation near Mandan, N. Dak. This phase of the experiment, however, represents only part of the results obtained. The effects of different systems and intensities of grazing upon the gains of the cattle would afford material for a study as detailed as the present one. In order to afford a clear understanding of the present study it will only be necessary to summarize the cattle gains, however, since these are directly influenced by the quantity of native forage available for grazing.

E. C. Chilcott,
Agriculturist in Charge.

PLAN OF THE GRAZING EXPERIMENT.

The arrangement of the pastures used for the grazing experiment near Mandan, N. Dak., is shown in Figure 1. Four pastures are operated under a system of continuous grazing. These are 100, 70, 50, and 30 acres in size and are grazed at the rate of one steer to 10, 7, 5, and 3 acres, respectively. In order to obtain different intensities of grazing a variation was made in the size of the pastures rather than in the number of cattle carried per pasture. This is as far as the plans for the experiment had been developed when it was started in 1915. It was aimed to have one pasture so large that it would be undergrazed and one so small that it would be overgrazed. During 1915 the 250 acres comprising the four pastures were fenced, and the area was grazed with fifty-three 2-year-old steers for approximately 115 days. The cross fences which separate the various pastures were constructed during the fall of 1915, and the grazing of the pastures, according to the outlined plan, started in the spring of 1916. The grazing in 1915 was preliminary to the experiment, which, at the time of preparing this bulletin, had been conducted on the four pastures that are grazed under the continuous system, for the six seasons from 1916 to 1921, inclusive.

The pasture designated as the "reserve" is used to carry the cattle before the experiment opens in the spring and after it closes in the fall. It is also used to carry four or five extra steers during the grazing season. These are held in reserve for use in case of accident to any of those in the regular pastures. During two or three different seasons it has been necessary to make use of one or more of the reserves, which made it possible to complete the season on a given pasture with the regular number of cattle. The cattle from the small pastures are removed to the reserve when their supply of forage has become exhausted.

While the original four pastures would furnish reliable information regarding the number of acres required per head for a con-

tinuous system of grazing, they did not cover the most important phase of the grazing problem from the standpoint of the native vegetation. A continuous system of grazing does not take into consideration the full requirements of plant growth, nor does it afford the maximum utilization of the vegetation without the serious effects, both to the cattle and the vegetation, attendant upon close grazing.

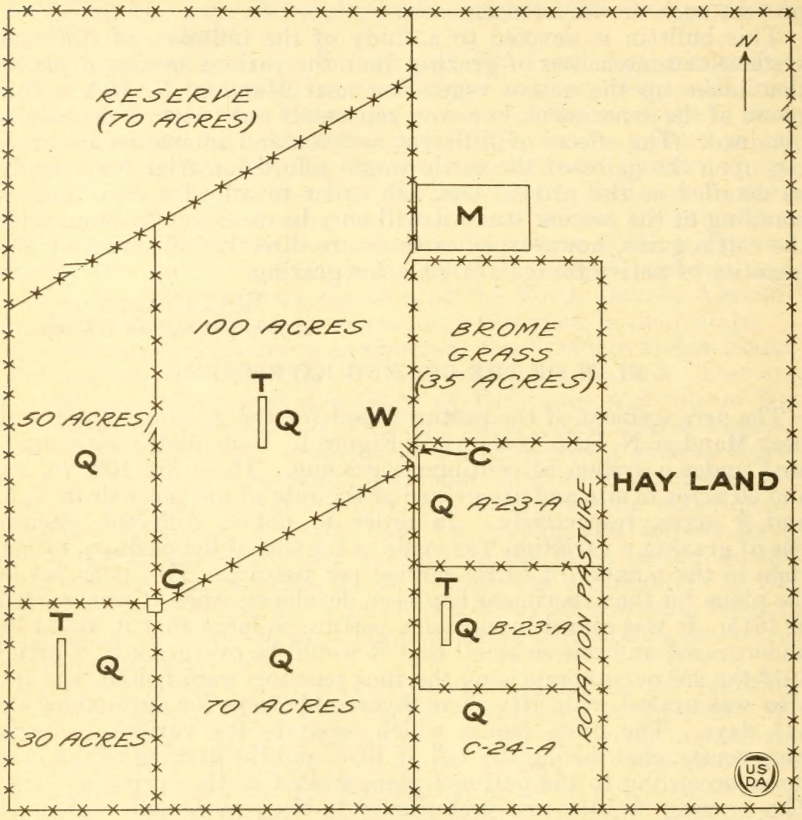

FIG. 1.—Field plan of the pastures used in the cooperative grazing experiment: T, Isolation transect; Q, mapped quadrats; C, corrals and water trough; W, deep well; M, mowing experiment.

The United States Department of Agriculture has for a number of years been conducting investigations in connection with grazing problems. The benefits to the vegetation of "rest periods" and the "alternation of pastures" have been advocated for some years,[1] and as early as 1895 rotation grazing was discussed as follows:

Clearly, then, if the grazing quality of the ranges is to be improved, they must be so treated that the nutritious native species of grasses and forage

[1] Smith, Jared G. Grazing problems in the Southwest and how to meet them. U. S. Dept. Agr., Div. Agros., Bul. 16, 47 p., 9 figs. 1899.
Cotton, J. S. Range management. *In* Yearbook, U. S. Dept. Agr., 1906, pp. 225–238, pl. 12. 1907.

plants can spread by means of the ripened seed. This can be accomplished by dividing the range up into separate pastures and grazing the different fields in rotation.[2]

The Forest Service of the United States Department of Agriculture later developed and put into practice in the management of grazing lands within the national forests the system of "deferred and rotation grazing."[3] A similar system has also been applied on a large range in the Southwest.[4]

In 1918 a 70-acre pasture managed under the system of deferred and rotation grazing was established. This is locally referred to as the "rotation pasture." It is not a new system of range management developed with the experiment at Mandan, but rather a direct application in the northern Great Plains of a system of grazing already highly developed. This system, as applied in this experiment, follows closely the detailed plan outlined in the Yearbook for 1915.[5] The only change made at Mandan, in the plan, is to transfer the cattle from the division grazed in the fall to the one grazed in the spring of the same year. This is done for a short time near the close of the season when the feed supply in the fall division becomes short and inferior to that in the spring division. There is usually some growth made in the spring division after the cattle are transferred to another unit. If this growth is grazed after maturity there are no ill effects to the vegetation, and there is no reason why this secondary growth should not be utilized if necessary. Another change is that the number of cattle is not reduced during the second season of fall grazing on a unit.

In 1921 a field of brome-grass was established adjoining the pastures. This will be grazed in direct relation to the native pastures under the continuous system of grazing and should furnish information on the relative value of a cultivated grass as compared with the native vegetation for grazing purposes. It was planned to start this pasture in 1919, but the seasons were so unfavorable that it was not possible to do so until the spring of 1921. The addition of the cultivated pasture now makes the grazing experiment very complete without being too complicated. While it would have been desirable to start all pastures at the same time, the fact that they were not so started should not make the results obtained any less valuable. Each pasture or system of grazing must stand on its own merit. In order to be of most value, a pasture under any system of grazing must maintain its productiveness over a series of years and not be greatly influenced by conditions that may obtain for one or two seasons only.

LAND USED FOR THE EXPERIMENT.

The area of land used for the grazing experiment was formerly a school section, located about 3½ miles south of Mandan, upon what is locally known as the Custer Flats. The section for a number of

[2] Smith, Jared G. Forage conditions of the prairie region. *In* Yearbook, U. S. Dept. Agr., 1895, pp. 309–324, figs. 70–74. 1896.

[3] Sampson, Arthur W. Range improvement by deferred and rotation grazing. U. S. Dept. Agr. Bul. 34, 16 pp., 5 pls. 1913.

[4] Jardine, James T., and Hurtt, L. C. Increased cattle production on southwestern ranges. U. S. Dept. Agr. Bul. 588, 32 pp., 12 pls., 2 figs. 1917.

[5] Jardine, James T. Improvement and management of native pastures in the West. *In* Yearbook, U. S. Dept. Agr., 1915, pp. 299–310, pls. 69–72. 1916.

years previous to 1915 had been used as hay land. Legislative action, both State and National, made it possible for the United States Department of Agriculture to obtain this section in lieu of two other sections of public land in North Dakota. This land when obtained in 1915 was considered worth about $35 per acre.

The section is level prairie with the exception of about 100 acres in the northwest corner, which is rolling and cut by ravines. This rough land is practically all in the reserve pasture and is not included in the area used in the experiment, the soil of which does not differ naturally from other vast areas in the western part of North Dakota. The first objection that might be raised regarding this section is that it is too good for grazing. This may be true, but it is not too good for a grazing experiment. No one connected with this experiment would advise using similar land for grazing purposes, especially when rough land is available. The land is so uniform that the pastures are as comparable as it could be hoped to obtain them. Uniformity of the land and uniformity of the vegetation are the conditions that are absolutely necessary in order properly to conduct an experiment of this kind and secure reliable results. It is necessary to eliminate all unknown factors as far as possible. The factors of uniformity of land and vegetation need cause no special difficulty in connection with a consideration of the results obtained in this experiment.

Another question that arises in regard to the experiment is, will the results obtained be applicable to other parts of the Great Plains? It should be recognized that the present experiment is designed to determine the effects of different systems and intensities of grazing upon the native vegetation and the cattle dependent upon it. The results of this experiment should apply to any area of land in the northern Great Plains having a similar plant cover that produces enough vegetation to be of grazing value. The unit area of land required for the best system of grazing will vary in different localities and can not be determined in any one area for all sections. The value of the results of this experiment is dependent upon the determination of the best system of grazing to follow in order to maintain the range at a high degree of productiveness. Any system that will accomplish this will also improve a range that has already been depleted by overgrazing. It is believed that the results recorded in these pages will apply to most of western North Dakota and South Dakota and to parts of Wyoming and Montana.

This land in 1915 would have been considered in excellent condition for grazing, not because of the very favorable season, but because of the normal density of the vegetation. The area had not, at least within recent years, been depleted by overgrazing. The experiment was, therefore, started on land that was in a high state of production of native forage. The problem was not to bring back into a state of productiveness an area that had been depleted by overgrazing, but rather to determine the best method of utilizing a satisfactory stand of forage. In order to study the other side of the problem it was first necessary to overgraze a pasture. This was designed to be done in the 30-acre pasture. This pasture is still being heavily grazed, and it will be some time before it is ready for the

restoration process. The depletion or destruction of the native vegetation by overgrazing with cattle does not occur suddenly;[6] it is cumulative, and an overgrazed pasture may continue to produce a limited quantity of feed for a number of years.

RELATION OF PRECIPITATION TO NATIVE FORAGE PRODUCTION.

The amount of precipitation during April and May exerts a greater influence upon the annual production of native forage than upon the production of small-grain crops during the same season. A normal rainfall during the early season practically insures a reasonable growth of native forage, even though the later rainfall is below normal. Such a condition may mean a very light crop or the failure of the small grains. This point was well illustrated during 1921. The rainfall during April and May was above normal, while during June and until the last week in July it was much below normal. As a result the native forage produced more than in 1920, while the small grains were decidedly reduced in yield.

The mean annual precipitation for the 45-year period from 1875 to 1919, inclusive, was 17.17 inches.[7] The mean seasonal precipitation from April 1 to August 31, inclusive, was 11.84 inches during the same period. The month of maximum precipitation is June, with a mean of 3.51 inches for the 45-year period.

TABLE 1.—*Annual precipitation near Mandan, N. Dak., by months, for the 6-year period from 1916 to 1921, inclusive.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal, Apr.–Aug.	Annual.
1916	0.28	0.09	1.88	0.93	1.69	2.25	3.55	2.04	0.92	0.27	0.07	1.10	10.46	15.07
1917	.28	.19	.35	1.87	.35	2.56	1.58	.89	1.97	.05	.03	.19	7.25	[1] 10.31
1918	.20	.11	.45	2.61	2.45	.68	2.47	2.03	.63	.27	.45	1.02	10.24	13.37
1919	.08	.80	.83	1.72	3.95	1.12	.85	1.22	.49	.98	1.19	.25	8.86	13.48
1920	.52	.20	1.21	.58	1.72	1.85	2.68	1.81	1.29	.25	.37	.21	8.64	12.69
1921	.18	.09	.79	2.59	3.05	.82	3.38	.25	1.58	1.39	.87	.24	10.09	15.23
Mean	.26	.25	.92	1.72	2.20	1.55	2.42	1.37	1.15	.54	.50	.50	9.26	13.36

[1] Lowest during 47 years.

While the grazing experiment has been in progress it has passed through the driest series of years that have obtained in this section during the period of record. The driest consecutive six years previous to 1916 was from 1885 to 1890, inclusive, with an annual mean precipitation of 14.33 inches. The mean seasonal precipitation from April 1 to August 31, inclusive, for the same period was 10.05 inches. Table 1 shows the annual precipitation by months for the six-year period from 1916 to 1921, inclusive, i. e., during the period covered by the grazing experiment. The annual precipitation of these six years ranged from 10.31 to 15.23 inches and averaged 13.36 inches. The seasonal precipitation from April 1 to August 31, inclusive, for the same period averaged 9.26 inches.

[6] Wilcox, E. V. The grazing industry. Hawaii Agr. Exp. Sta., 91 pp. 1911. Bibliographical footnotes.

[7] Data based upon the records of the United States Weather Bureau at Bismarck, N. Dak., and those recorded since 1914 at the Northern Great Plains Field Station, Mandan, N. Dak.

DEFERRED AND ROTATION SYSTEM OF GRAZING.

This system of grazing is designed to allow each division of the pasture to mature a crop for two successive years before it is harvested by the cattle in the fall of each year. Grazing on each division is deferred and rotated, so that each unit has an equal chance to produce a maximum crop normally before it is disturbed.

The seeds of the grasses which are scattered on the ground are aided in their planting by the trampling of the cattle. This manner of reseeding is highly important in some sections.[8] However, in this region the advantage gained by reseeding for most of the species of plants is not as great as it would be in an area that has been overgrazed for a number of years. As far as it has been possible to determine, there has been no measurable increase in any of the species by reseeding in the rotation pasture. This has no doubt been influenced to some extent by the very unfavorable seasons. The greatest advantage gained here by this system of grazing is in the physiological effect upon the plants. The fact that the plants are allowed to mature a crop normally permits them to store up food in their root systems to aid in the production of the next year's crop. It is a well-recognized botanical fact that the surest way to kill plants is to keep them from producing green shoots. The continual removal of the early green shoots by grazing gradually reduces the vitality of the plants until they finally die. Some species are much more readily killed in this manner than are others. This fact is well illustrated in the case of *Stipa comata* (western needle grass). In the 30-acre pasture this grass has been greatly weakened and thinned out, while in the frequently clipped quadrats it has been entirely eliminated.

Figure 2 shows the plan of the deferred and rotation grazing system. Section 1 illustrates the system presented in the Yearbook of the Department of Agriculture for 1915, page 309. Section 2 illustrates a similar plan but one in which the two successive fall grazing periods proceed from C to A to B, while in section 1 they proceed from C to B to A. It will be noted that section 2 produces the more uniform pattern and is ready to repeat directly in 1924, while in section 1 it repeats indirectly in 1924. In section 1, division B has four rest periods in 1919 and 1920, which do not occur in any other division during the cycle. Section 1 has been followed in this experiment.

The seasonal grazing of the 70-acre rotation pasture illustrates the application and management of deferred and rotation grazing. These 70 acres are divided by cross fences into three parts, approximately equal in size. The divisions are designated A, B, and C. When this pasture was first grazed in 1918, division A was grazed first, or in the spring; division B second, or in the summer; and division C was allowed to mature its crop normally and was grazed third, or in the fall. In 1919 division B was grazed first, A second, and division C was again deferred until the third period, or after the crop had matured without disturbance. During the following seasons divisions A and B are in turn treated as was division C

[8] Sampson, Arthur W. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. *In* Jour. Agr. Research, v. 3, pp. 93–148, 6 figs., pls. 12–23. 1914.

during 1918 and 1919. The grazing starts each season, so that a division which for two years has been deferred until the fall before grazing is not grazed first but second. This is done to allow any seedlings that might start from the second year's seeding a chance to become more firmly established before the division is grazed. This is the reason that the cycle as outlined in Figure 2, section 1, is not ready to repeat directly in 1924.

The details of the system of deferred and rotation grazing are more fully discussed in other publications of the United States Department of Agriculture.[9]

The grazing periods at Mandan have been as follows: Spring, from May 15 or June 1 to July 1 or July 15; summer, July 1 or July 15 to September 1 or September 15; fall, from September 1 or September 15 to October 15 or November 1. These periods of grazing fit the requirements of the vegetation in a very satisfactory manner. In the spring the vegetation has made a good growth by May 15 or June 1 and makes rapid growth during the grazing period, so that the cattle obtain plenty of feed. In the summer period there is still some growth taking place, and a few species have matured. By the time the fall period is reached all the valuable species in the division unpastured to this time have matured their seeds and are ready for harvest. The three Artemisias, however, have not matured their seeds by this time, but these plants are weeds, and their propagation is undesirable. During the years the rotation pasture has

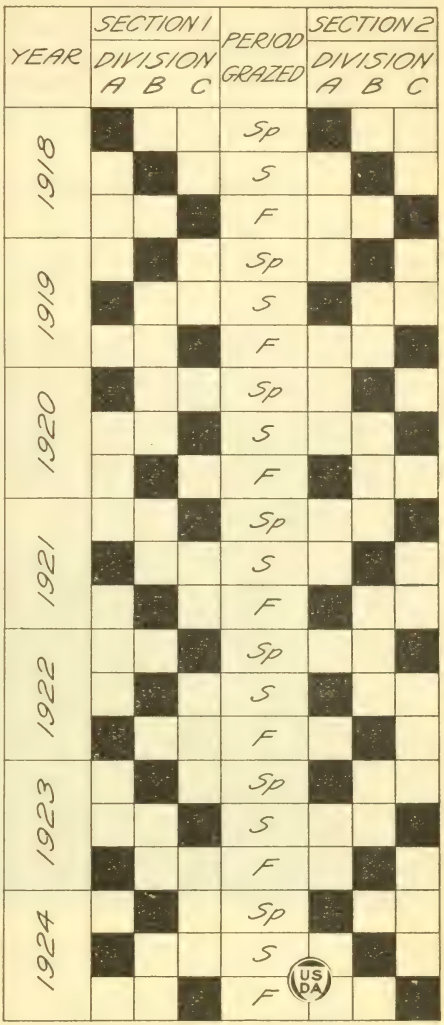

FIG. 2.—Diagram showing the order of grazing the three divisions of the deferred and rotation pasture for a complete cycle and the first season of the next. Columns *A*, *B*, and *C* represent the three divisions of the pasture. Each year is separated into three periods indicative of spring (Sp), summer (S), and fall (F) grazing periods. Grazing periods are shaded, rest periods unshaded. The first part of the diagram designated as section 1 illustrates the plan being followed; section 2 represents a more uniform plan that has been worked out. These sections differ in the order of the rotation. In section 1 the order of fall grazing is *C*, *B*, *A* and in section 2 *C*, *A*, *B*.

[9] Jardine, James T. Improvement and management of native pastures in the West. *In* Yearbook, U. S. Dept. Agr., 1915, pp. 299–310, pls. 69–72. 1916.
——— and Anderson, Mark. Range management on the national forests. U. S. Dept. Agr. Bul. 790, 98 pp., 4 figs., 32 pls. 1919.

been in operation there have been little heading and seeding of blue grama grass (*Bouteloua gracilis*) in the fall division. There have been heading and seeding of this grass in the spring-grazed division, however. Grazing or mowing seems to stimulate its production of flower stalks and heads. The vitality of the seeds is very low, and only a few ever germinate. This fact is further evidence that the value of this grazing system lies largely in the effects of normal development upon the plants.

PERIOD OF GRAZING AND CATTLE USED.

The period of grazing has been five months during the warm season. Grazing has started in the spring from May 15 to June 1 and continued to October 15 or November 1. Three years out of the

FIG. 3.—Two-year-old steers used in the grazing experiment. These steers are of the type used at the Northern Great Plains Field Station, near Mandan, N. Dak., during 1921.

six the seasonal grazing has started in May, and three years on June 1. This experiment does not take into consideration winter grazing, which should not be depended upon in this section of the Plains. The severe conditions of the winter of 1921–22 emphasize this fact.

The cattle used for the grazing work have been 2-year-old grade steers of the standard beef breeds. Figures 3 and 4 illustrate the type of steers that have been used.

The 2-year-old beef steer was decided upon as the unit, as (*a*) he seemed to be the unit most used by ranchmen figuring on this question; (*b*) he has about the average capacity for consumption between yearlings, cows, and large steers; (*c*) he is not disturbed, like the heifer, by periods of œstrum or by calving during the trial.[10]

[10] Shepperd, J. H. Carrying capacity of native range grasses in North Dakota. *In* Jour. Amer. Soc. Agron., v. 11, pp. 129–142, figs. 10, pls. 3–5. 1919.

WEIGHING THE CATTLE.

The most important feature of this experiment in relation to the cattle used is that they are weighed at regular intervals and their gains determined in much the same manner as in experimental feed lots. While the total gain of the cattle for the season is the measure of ultimate interest and importance, the gains for various periods of the season are also highly significant. The cattle have been weighed throughout the experiment at the end of regular 30-day periods. Whenever the grazing season has begun before June 1, the cattle have been weighed at the start in May and again on May 31. This has been done in order to make the gains correspond to the months. At the beginning and close of the season the cattle are weighed on three consecutive days and the average of the three weighings determined for the initial and final weights.

FIG. 4.—Two-year-old steers of the type used during the season of 1920. This group was on the rotation pasture.

When the experiment first started the cattle were weighed in two groups for each pasture except the ones on the reserve pasture, which were weighed individually. The cattle of all pastures are now weighed individually. This method of weighing has proved more satisfactory than any other, as the cattle do not become as excited at weighing time. In order to keep a record of the individual steers they are branded with serial numbers.

When the initial weights of the cattle are obtained the steers are divided into groups for the various pastures. The total weights of the different groups are made as nearly equal as possible. The average initial weight for 10 steers has been about 7,500 pounds. In dividing the cattle, attention is also paid to the matter of breeds, the aim being to make as nearly uniform groups for each pasture as possible. The cattle have free access to water at all times and

are not weighed until it has been determined that they have had sufficient water. They are weighed during the same time of day at each weighing. If the weights at the end of any period appear abnormal in any respect, they are checked the following day.

Figure 5 shows the corrals which are used to hold the cattle at weighing time. Figure 6 gives a near view of the rack around the scales. The gates to this rack are operated by means of ropes and pulleys, which greatly add to convenience in weighing the cattle.

GAINS OF THE CATTLE.

The gains of the cattle will be briefly discussed in order to show more clearly the relation between the quantity of native forage available for grazing and its influence upon the seasonable gains of the cattle. When the experiment started it was not definitely known how

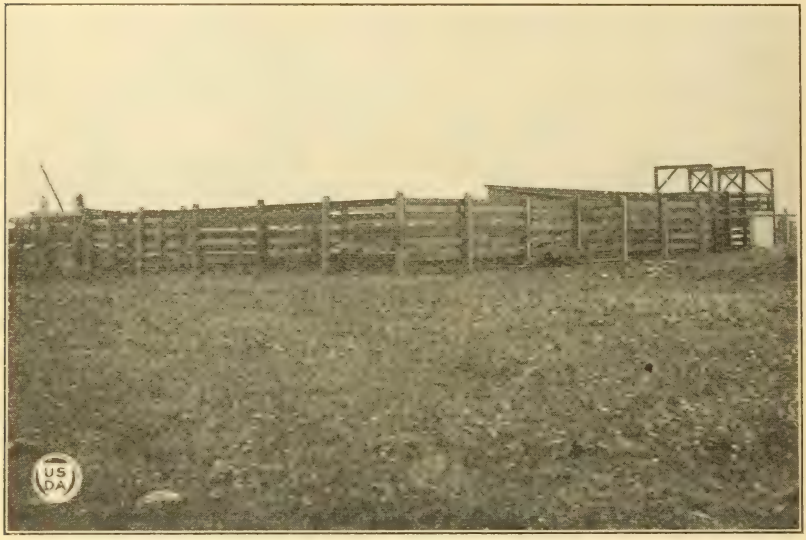

FIG. 5.—Corrals used to hold the cattle at weighing time. The scales are shown at the right.

much gain per head the native forage of this area was capable of producing. The average gains of the cattle for the period the experiment has been in progress are shown in Table 2. It will be noted that the highest gains per head are secured in the 100-acre and the 70-acre pastures. The gains of the cattle in these two pastures are now looked upon as the normal maximum gains per head that may be expected from the native forage. Both of these pastures had abundant feed left standing at the close of each season. Therefore, the quantity of available feed could not have been a limiting factor in the production of gains. This is also further shown by the fact that the gains in these two pastures have been practically equal. The small difference in favor of the 70-acre pasture is considered of minor significance. The gains in the 100-acre pasture may be influenced by its size and also by the fact that through it is the entrance to the

well and all other pastures. The cattle in this pasture are therefore more often disturbed than those in any other pasture, while those in the 70-acre pasture are the least annoyed.

The gains of the cattle in the 50-acre pasture show that they did not have enough feed to carry them through September with full gains. In the 30-acre pasture the cattle did not have sufficient feed to carry them through July with normal gains.

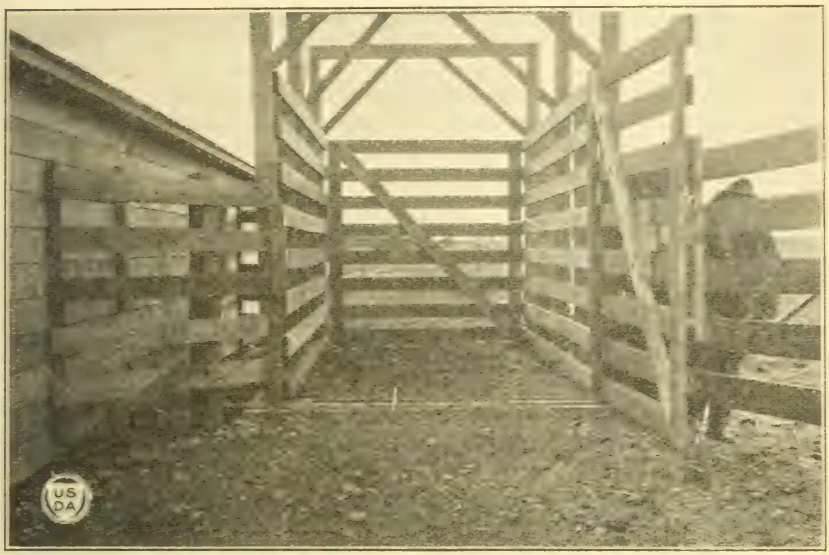

FIG. 6.—A close view of the rack on the platform of the scales. The gates are operated from the outside by means of ropes and pulleys.

TABLE 2.—*Average monthly and seasonal gains of 2-year-old steers, showing the increased weight obtained in the pastures continuously grazed for six years, 1916 to 1921, inclusive, and in the rotation pasture for four years, 1918 to 1921, inclusive.*[1]

Pasture.	Average total gains or losses[2] (pounds).											Average number.	
	Monthly.						Seasonal.[3]						
	May.	June.	July.	August.	September.	October.	Per pasture.	Per head.	Per acre.	Per 100 pounds live weight.	Per head, daily.	Steers per pasture.	Days grazed.
100 acres	[4] 347	1,084	628	540	403	47	2,875	287.5	28.6	38.3	1.92	10	150
70 acres	[4] 432	1,158	601	573	418	−24	2,942	294.2	42.0	39.1	1.96	10	150
50 acres	[4] 388	1,165	593	568	138	−217	2,441	244.1	48.8	32.8	1.65	10	148
30 acres	[4] 362	1,088	438	210	[5]−133	[6]−285	1,803	180.3	60.1	24.0	1.63	10	111
Rotation, 70 acres	[7] 843	1,364	710	712	314	−41	3,480	267.7	49.7	35.7	1.80	13	149

[1] Part yearlings were used in 1916 and 1918. The gains in the table have been reduced to a 2-year-old basis, differing but slightly from those obtained. When yearlings were used the number of cattle were increased to bring the total initial weight up to about 7,500 pounds.

[2] A minus (−) sign represents a loss.

[3] This average does not equal the sum of the monthly averages because of the nonuniformity of the grazing periods.

[4] Average for three seasons in which the cattle were started on the pastures in May.

[5] Average for parts of month during three seasons.

[6] Loss for one season in which the cattle finished the season on the pasture.

[7] Average for two seasons that the cattle were started on the pasture in May.

The rotation pasture was grazed with the same number of cattle as the other pastures during 1918 and 1919. However, the cattle did not gain as much as those in either the 100-acre or the 70-acre pasture. This was not because of a shortage of feed or a difference in kind of feed, but may be traced directly to the watering facilities, which are not as satisfactory for this pasture as for the others. The cattle each season spend a good deal of time in the lane leading to the water trough. In 1920 the number of cattle in the rotation pasture was increased to 15, and in 1921 to 17. In 1921 this pasture was grazed too close to produce its highest gains per head. From the percentage of the foliage cover removed by grazing in this pasture during 1918 and 1919, it is quite clear that it would have readily supported more cattle. Therefore, the gains produced since the number of cattle has been increased are of more significance than they would otherwise have appeared. The aim in this pasture is to utilize the maximum quantity of vegetation without too greatly reducing the gains per head of the cattle. Since the number of cattle in the rotation pasture has been increased it has produced higher gains per head than either the 50-acre or the 30-acre pasture, with practically an equal utilization of the native vegetation and without injury to it.

During only one year (1916) have the cattle on the 30-acre pasture finished the season on it. The rule that has been followed is to leave the cattle on the pasture until they show a decided loss in weight. This loss has ranged from 25 to 50 pounds per head. Had the quantity of visible forage been used as the measure of the time for their removal, they would have been removed earlier each year. It is always true that the cattle will remain on the pasture for days without loss in weight when they have no apparent forage supply before them. The loss usually comes suddenly and may occur within 5, 10, or 15 days. When the pasture becomes short the cattle are weighed every 5 or 10 days to determine when loss begins. When continual loss in weight is clearly established the cattle are removed to the reserve pasture for the rest of the season.

From Table 2 it will be seen that the cattle on the 100-acre, the 70-acre, and the rotation pastures show either light gains or losses for the month of October and somewhat reduced gains during September. The lowered gains during the latter part of the season do not necessarily condemn fall grazing. This is the time when cattle put on the "finish" so often referred to by stockmen, which is apparently a hardening process brought about through a reduction in the quantity of water that they drink, as well as a change in the condition of their flesh. Therefore, when cattle are without feed or water for 24 hours in the fall they will "shrink" less than they would during the same length of time earlier in the season. The autumn also represents the transition or adjustment period of the cattle between summer and winter. The cooler weather of autumn always causes shrinkage of the cattle, which is recorded as a loss in weight.

During the five years that the steers on the 30-acre field have been removed from their pasture they were on the reserve pasture for an average of 47 days. During this time they made an average total gain of 860 pounds, as compared with 370 pounds for the steers on the 100-acre and 351 pounds for those on the 70-acre pasture. The

gains produced in the latter two pastures during the 47-day period, as compared with the earlier gains, indicate that the fall or mature condition of the vegetation may have a pronounced influence upon the gain. However, the gains made by the steers from the 30-acre field during the same period on the reserve pasture strongly indicate that the condition of the cattle exerts an influence on the gains as great as or greater than that due to the condition of the vegetation. The cattle on the 100-acre and the 70-acre pastures have been on full feed all summer. They have therefore been able to put on the maximum gains which the native vegetation is capable of producing by the time it is fully mature. The steers on the 30-acre pasture, on the other hand, have been forced to graze a short range and have therefore not been able to make the maximum gains which an abundant supply of native vegetation is capable of producing. Therefore, when they obtain full feed in the reserve pasture they are in a condition to put on gains more rapidly than steers that have been on full feed up to that time. The fall gains of these steers are all the more remarkable when it is considered that they are made notwithstanding the general tendency to shrink during cool weather.

PERCENTAGE OF VEGETATION ANNUALLY REMOVED BY GRAZING.

Table 3 shows the estimated percentage of foliage cover annually removed from the different pastures by grazing. The quantity removed is estimated, because any more exact measurement, such as mowing, would disturb the condition of the pasture more than the annual grazing. When no vegetation is removed, as in an ungrazed pasture, there is 100 per cent foliage cover for the season. If all the vegetation has been consumed by the grazing cattle 100 per cent has been removed. Other estimates are based on these two conditions. Plate I shows two conditions of the same area, Figure 1 showing the pasture when it was estimated that 15 per cent of the vegetation had been removed, and Figure 2 the same area later in the season when it was estimated that 65 per cent of the vegetation had been removed. It is recognized that the personal equation influences any estimate, but the fact that the estimates have been made by the same person for the different seasons increases their value. However, the relative quantities are the important factors and show clearly the degree of grazing. In the 100-acre pasture the average proportion of foliage cover that has been removed is 51 per cent. This fact would almost lead one to assume that grazing at the rate of one head to 5 acres would furnish sufficient feed for the season. However, the 50-acre pasture shows that this is not enough, as the cattle lose weight because their feed is gone before the end of the season. The 70-acre pasture, with an annual average of 74 per cent of the foliage cover removed by grazing, has produced sufficient feed to carry the cattle through the season with maximum gains per head. This would strongly indicate that in order to insure sufficient feed and not overgraze under a system of continuous grazing, from 15 to 25 per cent of the foliage cover should remain on the pasture at the close of the season. To make a greater utilization of the forage a different system of grazing must be adopted. Since the number of cattle has been increased in the rotation pasture, over 90 per

cent of the vegetation has been removed by grazing. The gains of the cattle per head have been between those of the steers on the 100-acre and the 70-acre pastures and the two small pastures. The gains of the rotation steers during the past two years have been produced on a basis between 4 and 5 acres per head. The quantity of the vegetation remaining on a pasture at the close of the season indirectly determines its grazing capacity under a system of continuous grazing. However, under a system of deferred and rotation grazing the vegetation remaining on a pasture at the close of the season has no bearing upon its grazing capacity but more nearly determines the utilization of the forage. Under this system a larger percentage of the vegetation can be removed annually without reducing the gains of the cattle to the lowest point and without the injury to the vegetation attendant upon close continuous grazing. From the above facts it is clear that a high percentage of foliage cover removed means a lowered gain of the cattle. One reason why the cattle in the rotation pasture are able to produce higher gains per head on an acreage lower than the 50-acre pasture is because of the advantage derived by the vegetation from the rest periods. Another reason is that the cattle do not have to remain long at a time on a division with a rapidly diminishing food supply.

TABLE 3.—*Estimated percentage of foliage cover annually removed from the different experimental pastures by grazing.*

Year.	Cover removed from pastures (per cent).				
	100 acres.	70 acres.	50 acres.	30 acres.	Rotation (70 acres).
1916	30	50	70	95	.....
1917	40	65	90	100	.....
1918	55	75	100	100	80
1919	55	85	100	100	50
1920	60	85	100	[1] 95	90
1921	65	85	100	[1] 95	95
Average	51	74	93	98	79

[1] Not all *Artemisia frigida* taken.

It has been stated that "the maximum number of cattle that can safely be carried on any square mile of territory is the number that the land will support during a poor season." [11]

The above statement is literally true. From the results of the experiment herein reported it might be more correct to say that "the determining factor is the number of cattle that can be grazed during an average season." During years of very severe drought, such as sometimes occur on the Great Plains, no system of grazing can be expected to furnish feed for the normal number of cattle. It would not be advisable, though, to reduce the number of cattle in all seasons to meet an isolated condition; it is considered advisable, however, to regulate the number of cattle to fit an average season rather than to attempt to adjust the number to fit the varying seasons. Under such an arrangement a season below normal will mean close grazing and

[11] Smith, Jared G. Forage conditions of the prairie region. *In* Yearbook, U. S. Dept. Agr., 1895, pp. 309–324, figs. 70–74. 1896.

FIG. 1.—VIEW ACROSS THE QUADRAT AREA IN THE 100-ACRE PASTURE. JULY 15, 1921.

At this time it was estimated that 15 per cent of the foliage cover had been removed by grazing.

FIG. 2.—SAME AREA SHOWN IN FIGURE 1, PHOTOGRAPHED IN OCTOBER, 1921.

At this time it was estimated that 65 per cent of the foliage cover had been removed by grazing.

FIG. 1.—VIEW ACROSS THE QUADRAT AREA IN THE 30-ACRE PASTURE.

The composition and density of the vegetation are shown as they appeared before grazing in July, 1915.

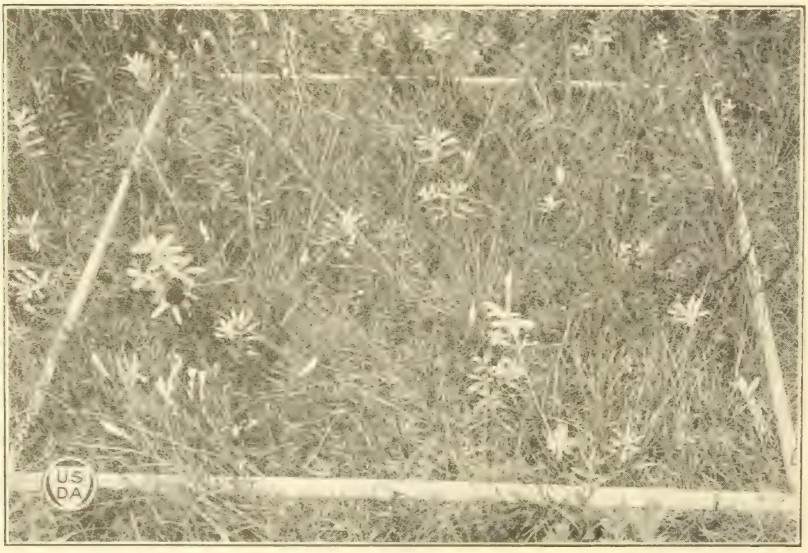

FIG. 2.—CLOSE VIEW OF THE QUADRAT THAT IS MAPPED IN DETAIL IN THE 100-ACRE PASTURE. JULY, 1915.

reduced gains, while one above normal will produce normal cattle gains and the vegetation will benefit by the lighter grazing. In other words, it is better to regulate the intensity of grazing, so that during good years the vegetation is benefited instead of attempting to consume all the forage by increasing the number of cattle. This is more likely to insure the maintenance of the pasture in a high state of production.

MEASURE OF EFFICIENCY OF A PASTURE OR SYSTEM OF GRAZING.

From Table 2 it will be noted that the steers in the 30-acre pasture have made the highest average total gain per acre. This does not mean that this pasture is the best or that the most desirable grazing system was used there. If the total gain per acre is to be accepted as the sole measure of efficiency of a grazing system, then the 30-acre unit is most efficient for the utilization of the native vegetation. However, since the number of cattle has been increased in the rotation pasture, the total gain per acre produced in that inclosure has been the highest obtained. The rotation pasture has also produced a total and individual gain per acre during the past two years greater than the combined gains of the 50-acre and the 30-acre pastures. The larger gain was produced on fewer acres with a lesser number of cattle. These facts bring out the point that the high gain per acre in the 30-acre pasture has not been obtained because the cattle have done exceptionally well, but because they made 94 per cent of their gain during the first 65 days of the season on a very limited acreage. In doing this they produced the lowest gain per head, however, and were moved to another pasture before the end of the grazing season.

The fact that the steers on the 30-acre field were removed from their pasture as soon as they showed a decided loss in weight has contributed to their high gain per acre. It is obvious that if they had been forced to remain on the pasture long enough the result could easily have been made to equal no gain per acre. Had the cattle continued to lose at the average rate used as the index for their removal, they would have lost the gains made in less time than they were put on. However, it is clear that the rate of loss would have increased during the time they would have been without feed.

From Table 4, which shows the average daily gain per head for the period the steers remained on the 30-acre pasture, it is clear that all other pastures have produced a greater gain. This fact also indicates that the gain per acre alone is not the most dependable index as a measure of a pasture. The purpose of the experiment on this pasture has been to abuse the vegetation by severe grazing and not to produce a high or low gain per acre. This has been accomplished in a very satisfactory manner to date. If the number of cattle had been reduced in order to maintain them on the pasture the full season, the grazing rate would have approached that of some of the other pastures and the purpose would have been defeated.

If a high individual gain per acre is desired regardless of other factors, one must be content with a low gain per head during the early part of the season. If, on the other hand, the maximum gain per head is desired, an essential for the best beef market, the acreage

must be increased so that the cattle will have an abundance of feed before them at all times, and as a result the per-acre gain will be reduced. While a high individual gain per acre might on casual consideration appear to be the most desirable measure of efficiency of a pasture or system of grazing, other factors should not be underestimated. For example, the vegetation in the 30-acre pasture has been injured by the close early grazing. This factor, however, does not lend itself readily to definite measurement, because it is cumulative and may not be apparent until a pronounced reduction has occurred in the grazing capacity of the area. This effect is best determined by the seasonal gains per head of the cattle and the condition of the vegetation. The injury to the vegetation must be given relative consideration with the cattle gains, either per head, total per acre, or individual per acre, in the determination of a measure of efficiency of a grazing system. Another factor of much weight is the time of removal of the cattle from a pasture. A system of grazing that makes it necessary to remove the cattle from a given area by the middle of July or August in order to procure the maximum gain from it is not to be commended. The cattle are not ready or in the best condition for market at this time, nor is it desirable to start them in the feed lot so early in the season. If another pasture is to be provided for them, it would be better to enlarge the first one or reduce the number of cattle and graze it in such a manner as will carry the cattle the full season. This arrangement would also result in better gains per head.

TABLE 4.—*Average daily gains of 2-year-old steers for the period during which the 30-acre pasture was grazed in the years 1916 to 1921, inclusive.*

Year.	Days grazed.	Average daily gains per head (pounds).				
		100 acres.	70 acres.	50 acres.	30 acres.	Rotation (70 acres).
1916	150	1.93	2.08	2.04	1.86	.....
1917	115	2.37	1.98	2.24	1.08	.....
1918	105	2.31	2.44	2.27	1.48	2.11
1919	90	2.55	2.92	2.70	1.99	2.96
1920	90	2.77	2.82	2.41	1.96	2.76
1921	115	2.19	2.42	2.22	1.47	2.18
Average	111	2.35	2.44	2.31	1.64	2.50

In order to determine the most efficient system of grazing it is necessary to formulate a measure by which a pasture can be judged. Such a measure must include all the factors with which the problem of grazing is intimately concerned. If a single measure, such as the gains per head or per acre, is used, other factors which are correlated with it will not be given sufficient consideration. Therefore, the most efficient system of grazing is one that will insure sufficient forage during the entire season to produce the greatest total gain, with the least number of cattle on the minimum unit of land, without permanent injury to the native vegetation. The system of grazing that most nearly fulfills this measure of efficiency may not be the one that produces the maximum gain per head or the greatest individual gain per acre. In order to fulfill its requirements the

greatest total gain per pasture and per acre will be obtained. While the maximum gains per head or per acre may not be the most desirable measure of grazing efficiency, they are essential within certain limits. It is obvious that the number of cattle may be increased until the total gain secured is greater than for any other system of grazing. However, this may be carried to a point where the gains per head may be so reduced that 25 cattle will produce no greater total gain than that produced by 20 head on the same acreage under the same system of grazing.

The measure of grazing efficiency as formulated is not as difficult of attainment as might at first appear. In order to provide the greatest total gain per unit area, the native forage must be allowed to maintain its maximum power of production. Continual close grazing early in the season causes a reduced production of forage. Therefore, the vegetation must have a period of rest and be allowed to mature a crop normally before it is grazed. In order to avoid too greatly reducing the gains per head of the cattle by forcing them to graze a short pasture for a long period, they must be allowed to graze different units for shorter periods. Such a system of grazing will also insure the maximum utilization of the vegetation with the least injury to it. The deferred and rotation system of grazing will come nearer to fulfilling the requirements of the measure of grazing efficiency than continuous grazing on a larger or smaller acreage per head.

BOTANICAL STUDIES IN CONNECTION WITH THE EXPERIMENT.

The first step necessary in connection with this experiment was a complete survey of the native vegetation. Therefore, in 1915 an herbarium was collected, comprising between 275 and 300 species of plants. This has been enlarged during the succeeding years. The plants collected are practically all confined to the highlands or prairie. Of the total number of species from 50 to 60 are grasses. While a comparatively large number of species of plants grow on the prairie, only 25 or 30 are important from the standpoint of grazing.[12] Out of this number four species produce approximately half of the forage.

It was not only necessary to know the individual species of plants, but also to determine their relationship to each other. This phase of the work has been more fully discussed elsewhere.[13]

The vegetation of this section is not as complex as that in some other parts of the Great Plains; for example, at Ardmore, S. Dak. The composition of the vegetation is remarkably uniform throughout the area. This fact tends to minimize complications in recording the effects of grazing.

The composition of the vegetation is very clearly illustrated in Plate II, Figure 1. The season of 1915, when the photograph shown in this illustration was taken, was very favorable, and all plants reached their maximum development.

[12] Sampson, Arthur W. Important range plants: Their life history and forage value. U. S. Dept. Agr. Bul. 545, 63 pp., 56 pls. 1917.

[13] Sarvis, J. T. Composition and density of the native vegetation in the vicinity of the Northern Great Plains Field Station. *In* Jour. Agr. Research, v. 19, pp. 63–72, 2 figs., pls. 12–14. 1920.

The dominant plant species are *Bouteloua gracilis*, *Stipa comata*, *Carex filifolia*, and *Carex heliophila*.[14] The total basal cover[15] of the vegetation is approximately 60 per cent, which would mean 6 forage acres in every 10. *Bouteloua gracilis* and *Stipa comata* have a basal cover of approximately 20 and 10 per cent, respectively, while that of the two species of Carex combined is less than 10 per cent.

The composition and density of the vegetation are not only highly important in relation to immediate grazing, but also in regard to systems and intensities of grazing. The vegetation on the area selected for the grazing experiment is one of high vegetative development, or the climax type. Grazing on such an area should be so adjusted that the composition and density of this climax type are maintained as nearly as is consistent with the best utilization of the forage. Grazing is necessarily a more or less destructive process, and unless reasonable precautions are taken its effects on a given area are likely to become cumulative and cause serious deterioration of the native range.

In the utilization of lands as grazing areas, the invasion by the higher type of vegetation is often prevented, especially where the species high in the development are grazed with greater relish than those lower in the succession. Thus, the plants well up in the development of the type may disappear gradually or suddenly, according to the degree of disturbance caused by the adverse factor, until the plant stages lower in the development predominate.[16]

The system or intensity of grazing, therefore, that will be best adapted to the type and composition of the vegetation found in this section of the Great Plains is one that will most nearly allow it to maintain its present development and production.

PLANS AND RESULTS OF THE BOTANICAL STUDIES.

In order to determine and follow the effects of different systems and intensities of grazing upon the native vegetation, a definite plan was formulated and has been maintained with slight modification. It was necessary, because of the pressure of other work, to confine the studies to those phases which seemed necessary to a clear understanding of the effects of grazing upon the native vegetation.

The following records have been found most useful in tracing the changes in botanical composition: (1) Mapped quadrats, (2) isolation transects, (3) list quadrats, (4) clipped quadrats, (5) photographs, and (6) general field notes.

MAPPED QUADRATS.

Carefully selected areas were established and charted in 1915. These were located in the open pastures and have been subjected to grazing. Maps (covering a square-meter quadrat) furnish a permanent record of the composition of the vegetation at the beginning of the experiment. They also show clearly the relationship of the different species of plants, especially those that grow in mats, such as the blue grama grass, and those that grow in bunches, like

[14] The "plant formation" of this region is "Mixed prairie." See Clements, Frederic E. Plant Indicators, xvi, 388 pp., 25 figs., 92 pls., pl. A (col.). Washington, D. C. 1920. Bibliography, pp. 364–373. (Carnegie Inst. Wash. Pub. 290.)

[15] Basal cover, as used here, means the extent of ground surface actually covered by plants after the foliage has been removed by grazing or clipping.

[16] Sampson, Arthur W. Plant succession in relation to range management. U. S. Dept. Agr. Bul. 791, 76 pp., 26 figs., 2 pls. 1919.

the western needle grass. They also show to a limited degree the effects of grazing upon the different species. Plate II, Figure 2, and Plate III, Figure 1, show the native vegetation as it appeared on the quadrats in the 100-acre and the 30-acre pastures, respectively, in 1915. Plate III, Figure 2, shows the quadrat in the 30-acre pasture after six years of severe grazing.

While maps have been made to show all species, two charts, Figures 7 and 8, are included, which show only the blue grama and western needle grasses. These are the two most important grasses

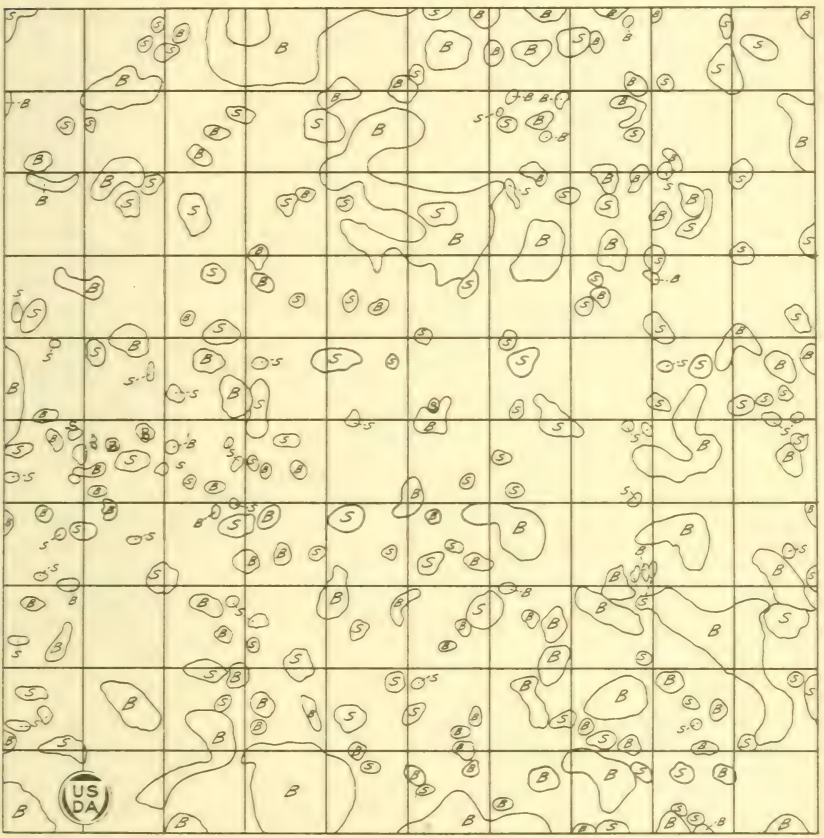

FIG. 7.—Square-meter quadrat in the 100-acre pasture, showing the relationship of Bouteloua and Stipa. Charted near the close of the grazing season in 1916. *Bouteloua gracilis* is indicated by *B* and *Stipa comata* by *S*.

from the standpoint of grazing, since they furnish the largest percentage of the feed. These maps were made in the 100-acre and the 30-acre pastures in 1916 and show the relationship of these grasses before the effects of grazing had become apparent. There is considerable difference noted between the same quadrats mapped in 1916 and 1920.[17] This difference is mainly in the size of the mats of blue

[17] The quadrat maps have been drawn free-hand. In 1918 a pantograph was obtained and tested for charting. However, it has not yet been used for this purpose. Its use in charting has been described by Hill. See Hill, Robert R., Charting quadrats with a pantograph. *In* Ecology, v. 1, pp. 270–273. 1920.

grama grass and the bunches of needle grass. The larger mats and bunches have broken up since 1916. The dry seasons have no doubt been of greater influence as a direct cause of this than has the grazing in the case of blue grama. Western needle grass has been greatly reduced in extent in the quadrat in the 30-acre pasture. This has no doubt been largely because of the intense grazing, since the reduction is twice as much as in the quadrat in the 100-acre pasture. This fact is further confirmed by observation and by the clipped quadrats. Western needle grass does not withstand severe grazing as well as

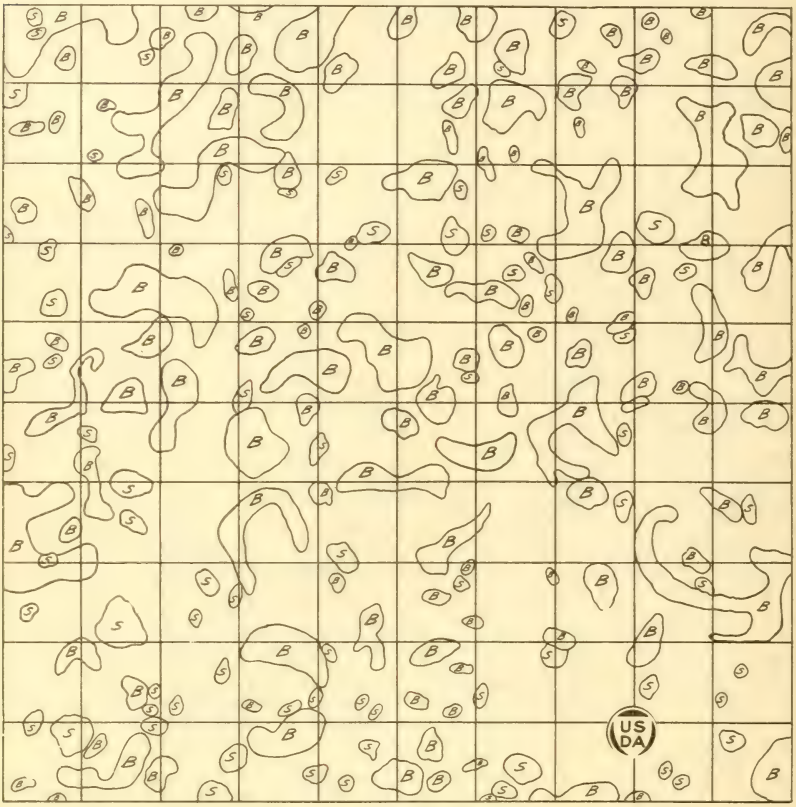

FIG. 8.—Square-meter quadrat in the 30-acre pasture, showing the relationship of Bouteloua and Stipa. Charted near the close of the grazing season in 1916. *Bouteloua gracilis* is indicated by *B* and *Stipa comata* by *S*.

blue grama. It is a shorter lived perennial and is more dependent upon reseeding. Western needle grass is the species that is benefited most by the system of deferred and rotation grazing.

ISOLATION TRANSECTS.

Areas that are now known as "isolation transects"[18] were set aside in the 100-acre and the 30-acre pastures in 1915. A similar area

[18] Dr. H. L. Shantz suggested these areas when he visited the station in 1915. Their designation as isolation transects was suggested by Dr. F. E. Clements when he visited the station in 1917.

was also set aside in one division of the rotation pasture in 1918. When the experiment was started the value of these transects was underestimated. It was not until 1919 that their real worth was appreciated. In Figure 9 is shown a diagram of one of these transects. The transect is 300 feet long; the units are each 20 feet square. One of the units in series A is opened to grazing each year,[19] while one of the units in series C is closed to grazing at the same time. Series B is not subject to grazing at any time, nor is the vegetation removed in any manner.

In the 30-acre pasture the isolation transect shows the points of most interest and significance in regard to the development of *Artemisia frigida*. In series A it is becoming thicker in the unit opened to grazing in 1918. The growth of this species in series B is no different from that in the 100-acre pasture. The maximum development of *A. frigida* is shown in series C, the units closed to grazing annually. The plants in the unit closed in 1918 are not greatly different from those in series B. The 1919 unit shows a slight increase in the number of plants, but they are about normal in size. The units closed in 1920 and 1921 show a greater increase in the number of plants and a pronounced increase in the vigor of the individual plants. Plates IV and V illustrate the difference in the thickness of the plants and their vigor. The photographs of the isolation transect in the 30-acre pasture, reproduced in these plates, show the effects of intense grazing for varying periods upon the native vegetation better than it can be recorded in any other way.

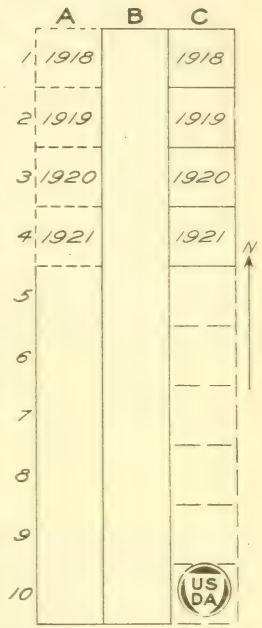

FIG. 9.—Diagram showing plan of isolation transects: *A*, Grazing series, one unit opened to grazing each year; *B*, permanent series, units never grazed; *C*, regeneration series, one unit closed to grazing each year. Solid lines show fences, dotted lines where fences formerly stood, and dash lines where fences will ultimately be built.

LIST QUADRATS.

List quadrats, square-meter areas in which the plants are counted and the numbers recorded, are of value in keeping a record of the number of plants of individual species. Their value is increased, since it is possible to include a comparatively large number of square-meter quadrats. These quadrats are located in the open pastures and in the isolation transects. They are permanently located by means of a single stake. There are 40 of these quadrats in each pasture. The highly important species are also recorded in an equal number of duplicate quadrats cornering the originals. It is possible to keep a record of individual species which appear as single plants or as single distinct bunches, such as *Aristida longiseta* or *Koeleria cristata*. Not all of the species that appear in the quadrats are recorded. The species that are regularly listed have been reduced

[19] Units were opened on the north end and closed on the south end in 1917. In 1918 they were placed across from each other.

to approximately 10 in number. Only those species that are the most abundant or significant are recorded, but the same ones are listed in all the quadrats. Out of the number that have been listed, three species stand out as of primary significance. These are *Artemisia dracunculoides*, *A. gnaphalodes*, and *A. frigida*. Of these *A. frigida* is of greatest importance, because it is an indicator of overgrazing [20] and because the cattle refuse to eat it until they are forced to do so. During the past two years the cattle in the 30-acre pasture have lost weight, while many of these plants were still standing in the pasture. Plate VI shows how many of these plants were left in the 30-acre pasture at the close of the grazing seasons of 1917 and 1921. From Figure 1 of this plate it will be noted that practically all plants were eaten in 1917, while Figure 2 shows numerous plants of *A. frigida* still standing at the close of the season in 1921. The cattle do not seem to hesitate about eating the other two species of Artemisia, though they do not take them as readily as most of the grasses. They begin to eat *A. frigida* when other feed becomes scarce in the small pasture. It is usual to see scattered over the pasture the stalks of this plant that the cattle have pulled off and spit out. This sage is bitter and distasteful to them and is therefore avoided. Plate VII illustrates the condition of the 30-acre pasture on July 15, 1919, and on the same date in 1921. The photographs here reproduced were taken at the time the cattle usually begin to eat *A. frigida* and afford a very clear idea of the effects of continuous overgrazing in relation to this species of sage. The dark plants in Figure 1 are *A. dracunculoides*. It will be noted that none of these plants can be seen in Figure 2.

TABLE 5.—*Number of plants of Artemisia frigida per square meter in 16 quadrats in the 100-acre and 30-acre pastures in 1915 and in the same square meters in 1920.*[1]

100-acre pasture.		30-acre pasture.		100-acre pasture.		30-acre pasture.	
1915	1920	1915	1920	1915	1920	1915	1920
10	3	0	4	0	1	0	5
2	1	0	1	0	0	3	8
4	11	0	1	0	0	2	4
9	3	2	4	3	1	0	5
2	0	0	8	3	1	0	6
1	1	0	3	1	2	3	10
4	5	0	2	0	0	3	6
10	6	4	11				
2	1	0	7	51	35	17	85

[1] These 16 square meters are not included in the 40 list quadrats previously discussed.

A. frigida (pasture sage) has increased about five times per unit area in the 30-acre pasture since the experiment started. There has been an increase not only in number but also in the size of the individual plants. Plate VIII, Figure 1, illustrates clearly the size a single plant may attain. The increase in number is best shown by Tables 5 and 6. In both the 100-acre pasture and the 30-acre pasture 16 quadrats were permanently located in 1915. They formed areas

[20] Shantz, H. L. Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains area. U. S. Dept. Agr., Bur. Plant Indus. Bul. 201, 100 pp., 23 figs., 6 pls. 1911.

FIG. 1.—CLOSE VIEW OF THE QUADRAT THAT IS MAPPED IN DETAIL IN THE 30-ACRE PASTURE. JULY, 1915.

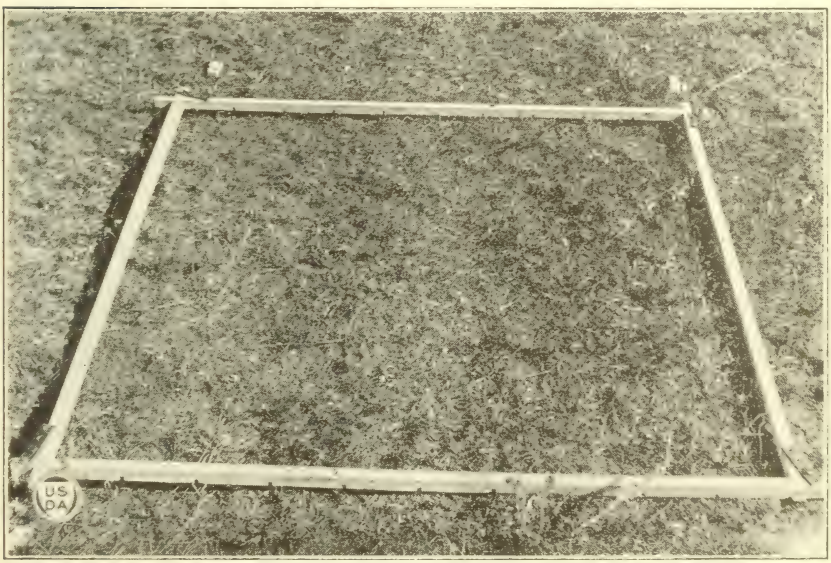

FIG. 2.—SAME QUADRAT SHOWN IN FIGURE 1, PHOTOGRAPHED IN OCTOBER, 1921, AFTER SIX YEARS OF SEVERE GRAZING.

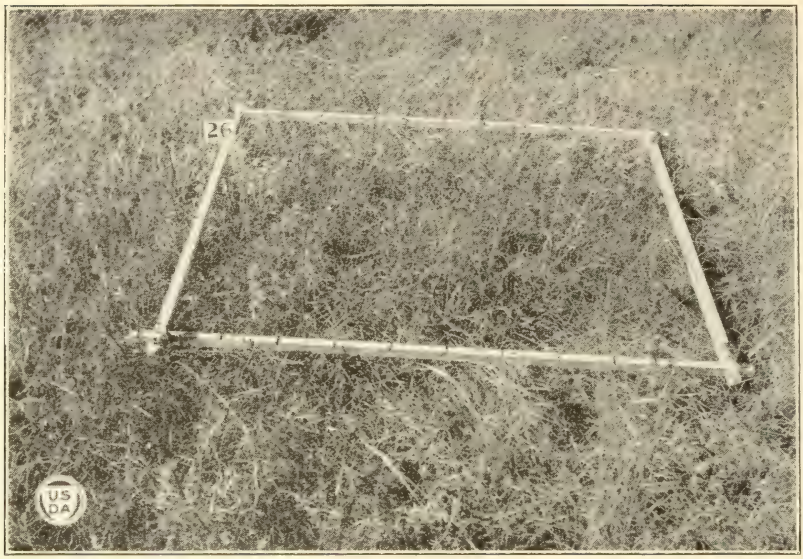

FIG. 1.—UNIT IN THE 30-ACRE PASTURE CLOSED TO GRAZING IN 1918.

Note the plants of *Artemisia frigida*, which are about normal in size and number. The top of the frame in each case marks the division between the closed units and those never grazed. October, 1921.

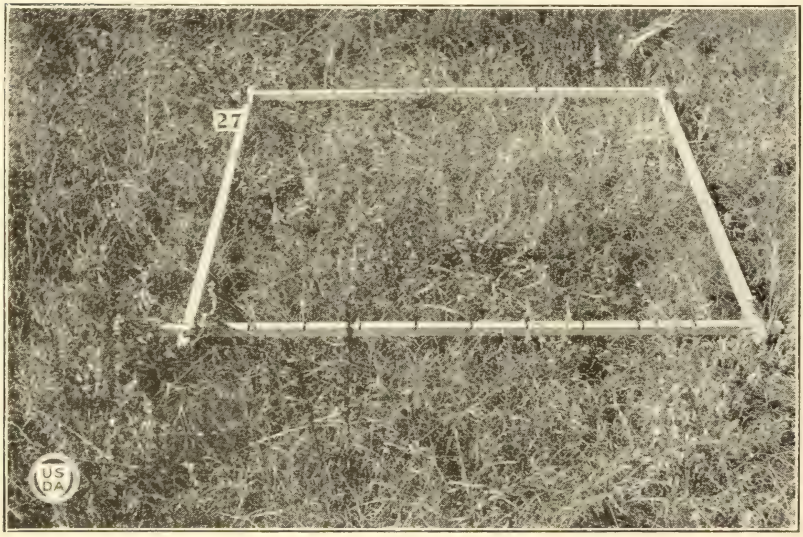

FIG. 2.—UNIT IN THE 30-ACRE PASTURE CLOSED TO GRAZING IN 1919.

Note the plants of *Artemisia frigida*, which are about normal in size but somewhat thicker on the ground than those shown in Figure 1. October, 1921.

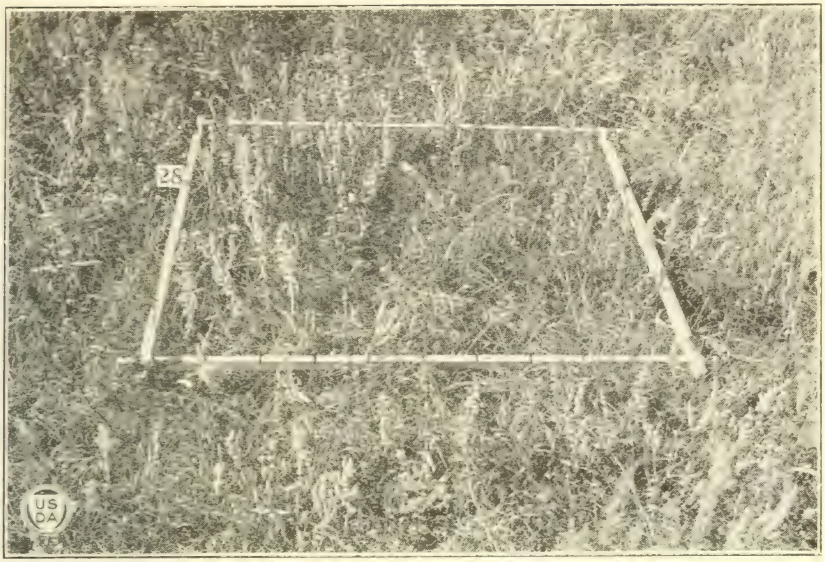

FIG. 1.—UNIT IN THE 30-ACRE PASTURE CLOSED TO GRAZING IN 1920.

Note the plants of *Artemisia frigida*, which are taller and more numerous than in the units closed in 1918 and 1919. October, 1921.

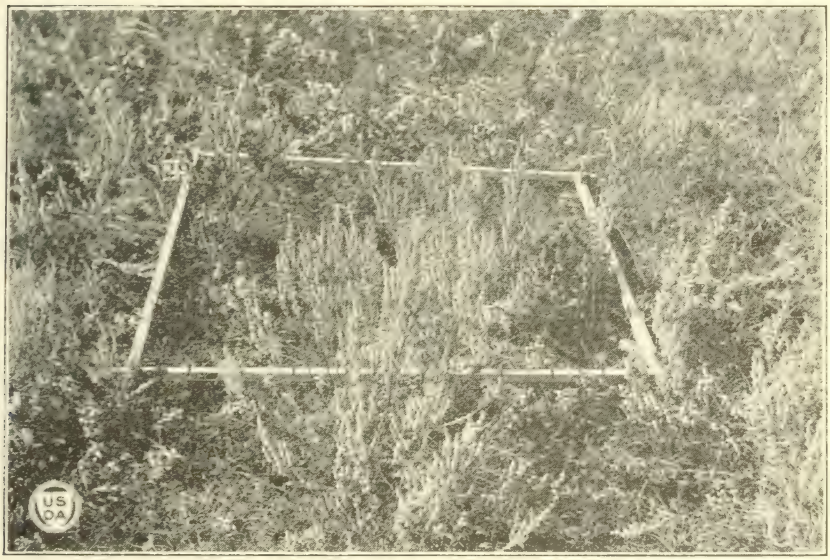

FIG. 2.—UNIT IN THE 30-ACRE PASTURE CLOSED TO GRAZING IN 1921.

Note the plants of *Artemisia frigida*, which are much larger, coarser, and thicker on the ground than in the units closed during the previous seasons. October, 1921.

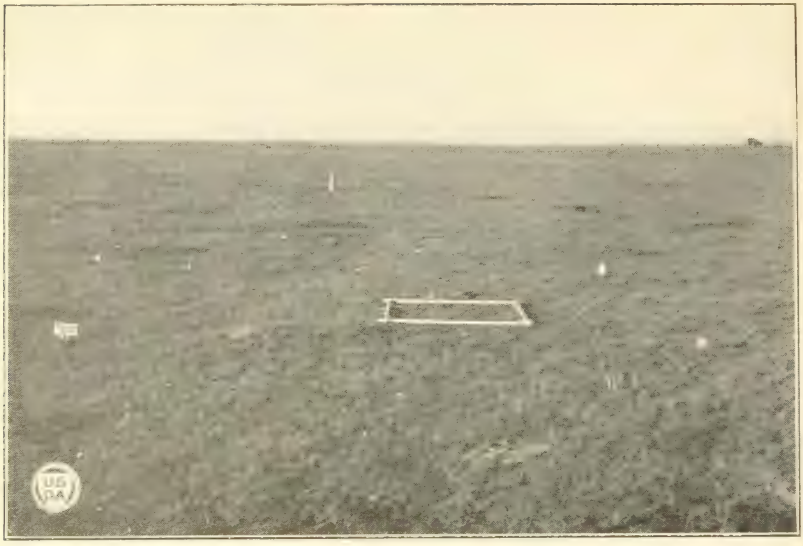

FIG. 1.—VIEW ACROSS THE QUADRAT AREA IN THE 30-ACRE PASTURE AT THE CLOSE OF THE GRAZING SEASON IN 1917.

Note that practically no vegetation is left standing. November, 1917.

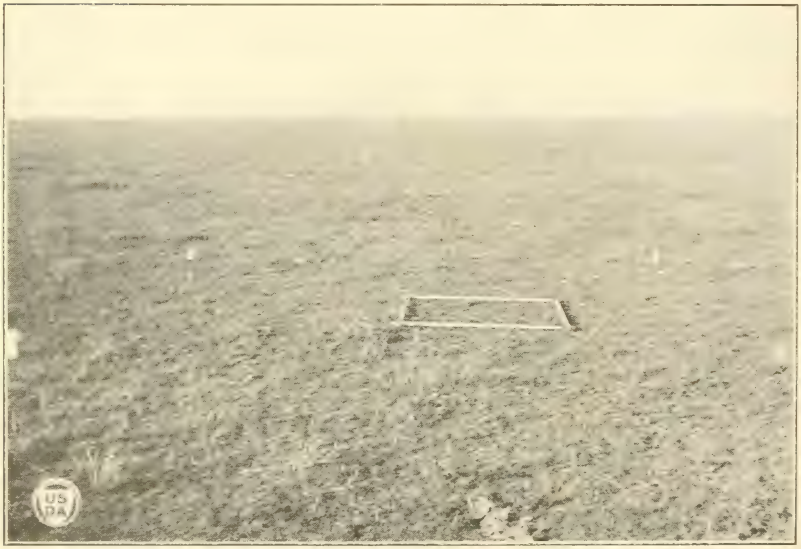

FIG. 2.—SAME AREA SHOWN IN FIGURE 1, PHOTOGRAPHED AT THE CLOSE OF THE SEASON IN 1921.

Note that a considerable number of plants of *Artemisia frigida* are left standing. October, 1921.

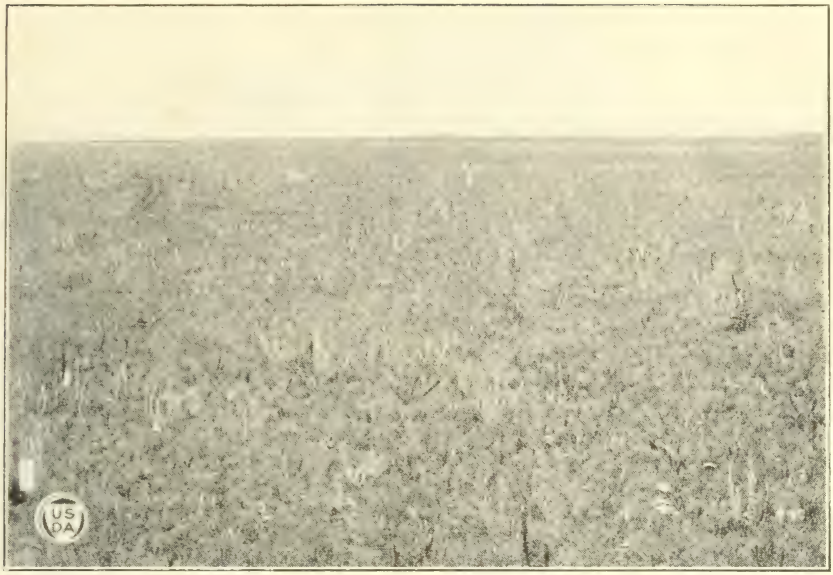

FIG. 1.—VIEW ACROSS THE QUADRAT AREA IN THE 30-ACRE PASTURE, SHOWING ITS CONDITION IN JULY, 1919.

Note that a considerable number of plants of *Artemisia frigida* are left standing and also some *Artemisia dracunculoides* (the dark plants). July 15, 1919.

FIG. 2.—SAME AREA SHOWN IN FIGURE 1, PHOTOGRAPHED IN 1921.

Note the large quantity of *Artemisia frigida*. The cattle usually begin to eat it by the middle of July. *Artemisia dracunculoides* does not appear at this time. July 15, 1921.

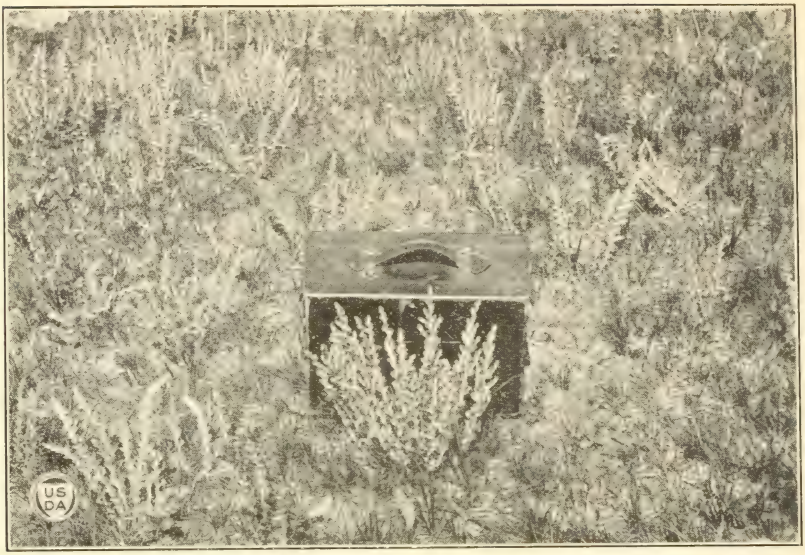

FIG. 1.—CLOSE VIEW OF A SINGLE PLANT OF ARTEMISIA FRIGIDA IN THE 30-ACRE PASTURE.

This plant was 10 inches tall and had 36 flower stalks. This affords an idea of the size a single plant may attain. June, 1920.

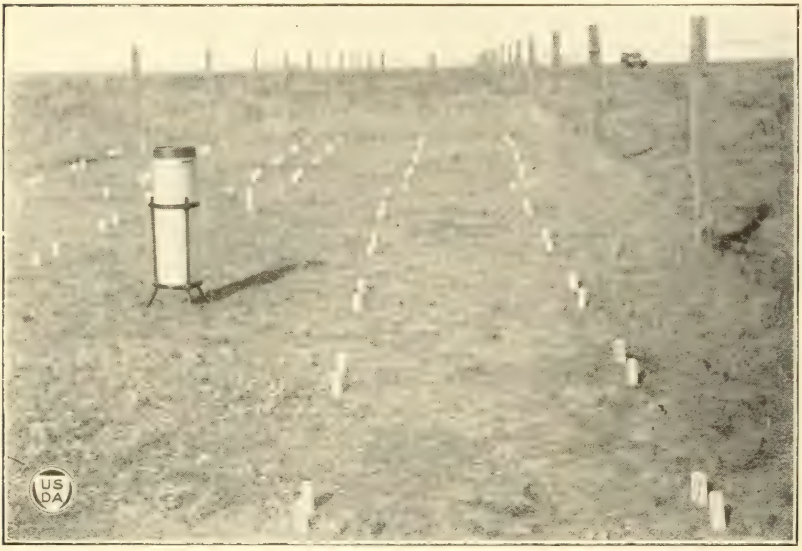

FIG. 2.—VIEW OF THE CLIPPED QUADRATS IN THE ISOLATION TRANSECT OF THE 100-ACRE PASTURE.

The quadrat cut every 10 days is in the foreground. The duplicates are on the left. October, 1919.

PLATE IX.

VIEW IN A PASTURE ADJOINING THE NORTHERN GREAT PLAINS FIELD STATION.

The white plants are *Artemisia frigida*, which have been favored by the heavy grazing in this pasture. July, 1915.

4 meters square, and the number of plants of *A. frigida* in each square meter was listed in 1915 and 1920. The results are presented in Table 5. This table shows that there has been a heavy increase of this species in the 30-acre pasture. The slight decrease in the 100-acre pasture is not great enough to be of any particular importance. There will be found a fluctuation in number from year to year, as some plants die normally, while others meet with accidents, such as being cut off by gophers or pulled up by the cattle. Under normal conditions a few new plants will be established each year, so that the total number remains about the same. However, as soon as some disturbing factor enters, such as the continuous intense grazing of the 30-acre pasture, this is the plant that is ready to take advantage of the weakened condition of other species.

Table 6 shows the number of plants of *A. frigida* in the units of the isolation transects. These show very clearly the effects of grazing upon this species. In the 100-acre transect practically no difference between the different units appears, but in the 30-acre transect there is a striking difference that can be accounted for only by overgrazing. The units that are annually closed to grazing contain the largest number of plants. The individual plants in these units also show pronounced differences, depending upon the length of time the unit has been closed. Table 7 presents these differences clearly.

TABLE 6.—*Number of Artemisia frigida plants per square-meter quadrat in the isolation transects in the 100-acre and 30-acre pastures in 1921.*

[Series A was fenced in 1915; the units are opened in succession to grazing, beginning with unit 1 in 1918. Series B is permanently closed to grazing. Series C is open to grazing except as the units are closed in succession, beginning with unit 1 in 1918.]

Pasture.	Series.	Number of plants per square meter.										
		Unit 1.	Unit 2.	Unit 3.	Unit 4.	Unit 5.	Unit 6.	Unit 7.	Unit 8.	Unit 9.	Unit 10.	Total.
100-acres	A	1	2	1	8	9	2	0	5	0	2	30
	B	5	11	5	5	6	0	2	1	0	2	37
	C	3	5	4	3	13	5	2	1	2	2	40
												107
100-acres (duplicate)	A	1	4	3	1	1	0	1	1	0	1	13
	B	5	3	0	11	5	3	5	2	3	0	37
	C	2	7	4	1	11	4	12	5	4	1	51
												101
30-acres	A	21	7	7	1	2	1	0	1	0	0	40
	B	1	5	3	1	2	0	0	3	0	1	16
	C	5	11	7	25	9	12	7	14	12	11	113
												169
30-acres (duplicate)	A	29	14	32	4	2	1	1	0	0	1	84
	B	0	1	2	0	2	0	3	5	0	1	14
	C	6	23	30	24	16	11	6	6	10	9	141
												239

From Table 7 it is very evident that not only the number of plants is influenced by overgrazing, but also the size of the plants, which is a good index of their physiological vigor.[21] This condition is brought about by reduction of the competition of other species. The vigor of the other species has been reduced by the continuous severe grazing, while the *A. frigida* has been favored, because the cattle do not like it and will not eat it until forced late in the season after it has had a chance to make its normal growth. Since the other species of

[21] Sampson, Arthur W. Plant succession in relation to range management. U. S. Dept. Agr. Bul. 791, 76 pp., 26 figs., 2 pls. 1919.

plants do not have a chance to make much growth, they do not use much of the soil moisture. Therefore, because *A. frigida* is left undisturbed until late in the season it has the advantage of nearly all the moisture available in the soil. It has increased in extent until the cattle will not clean up all of it before they lose weight. In the unit closed in 1918 the competition of other species had not been greatly reduced and the plants of *A. frigida* are in about a normal condition of growth. The competitive influence of other species has not been of much consequence in the units closed in 1920 and 1921. The increase in the number and the size of the individual plants has enlarged the area occupied by *A. frigida* in the 30-acre pasture about 10 times. It can thus be readily seen how this one plant can materially reduce the grazing capacity of a pasture.

TABLE 7.—*Average height, number of stalks per plant, and number of plants of Artemisia frigida per square meter in the units closed to grazing each year in the isolation transect in the 30-acre pasture.*

[Measurements made in the autumn of 1921.]

Year closed to grazing.	Average of 2 square-meter quadrats.		
	Height of plants.[1]	Stalks per plant.	Plants per square meter.
	Millimeters.	*Number.*	*Number.*
1918	177.5	5.9	5
1919	196.4	7.9	16
1920	289.6	8.0	18
1921	295.9	8.7	23

[1] Plants less than 50 millimeters in height were not included.

In 1920 the difference in the size of the plants of *A. frigida* was noted in the various pastures. Measurements were made of all the plants over 25 millimeters in height in the list quadrats. The results obtained are presented in Table 8.

TABLE 8.—*Average height, diameter, and number of stalks per plant of Artemisia frigida in the different pastures in 1920.*

Artemisia frigida.	Pastures.			
	100 acres.	70 acres.	50 acres.	30 acres.
Height of plants.....millimeters..	133.9	127.3	115.1	150.2
Diameter of stalks.....do....	15.2	15.4	13.4	18.1
Number of stalks.....per plant..	6.5	5.3	5.2	7.4

It will be noted that the plants in the 30-acre pasture are the largest in all cases, while those in the 50-acre pasture are the smallest, no doubt because the cattle in the latter pasture have so far been able to graze this plant enough to retard its most active stage of development. Therefore, it does not have the advantage over other species that it has attained in the 30-acre pasture. The cattle have remained on the 50-acre pasture longer during the season, and this fact has allowed them sufficient time to remove the plants gradually. The intensity of grazing also has its effect upon these plants, as the cattle have more feed before them. Therefore, the

other species are not so rapidly exhausted and the cattle are not forced to take the *A. frigida* all at once without access to anything else. The coarseness of the plant in the two pastures also influences its being eaten by the cattle. It seems the intensity of grazing in the 30-acre pasture early in the season is so severe that the *A. frigida* has been able to reach its highest degree of noxiousness, while in the 50-acre pasture the grazing has been just severe enough to keep it from reaching its stage of greatest activity and actually to weaken it. In the larger pastures this species has not been influenced by the grazing. The same general conditions of growth held true for *A. frigida* during 1921 as in 1920, but no measurements were made in the open pastures.

A. frigida spreads and increases by seed. Even when it appears that all vegetation has been removed by grazing, a few stalks of this plant are still found in the pasture. Each plant produces a large number of very small seeds, which are scattered over the ground, and some of them will become established wherever the conditions are favorable. The most favorable places for them to start are along old trails, on old gopher mounds, along old furrows, or on ground that has been trampled by cattle. They are therefore able to establish themselves in any place where some disturbing influence has reduced competition. The intense grazing and consequent heavy trampling of the cattle in the 30-acre pasture therefore afford an advantageous condition for the establishment of seedlings of *A. frigida*.

Another advantage that *A. frigida* has over other species is its ability to assume the nature of a shrub.[22] All the stalks do not die down to the crown each year. Some of them develop green leaves and shoots directly on the old stems early in the season and are therefore able to start the manufacture of plant food at once. Not all of the plants do this, but a number of them do. This early development of green leaves gives *A. frigida* an advantage which the other species do not possess. As far as has been observed all the other species that are common in the pastures die back to the ground each year, and new shoots develop directly from the crown.

In the case of the two other sages, *A. dracunculoides* and *A. gnaphalodes*, very few seed stalks are allowed to develop in the small pastures. The cattle will eat them long before they will touch *A. frigida*. However, in the 100-acre and the 70-acre pastures the three sages are usually not much disturbed by the cattle. The plants have not made unusual abnormal developments in these pastures. *A. dracunculoides* and *A. gnaphalodes* appear abundant and well developed each year, but there has not been an unusual increase in the number per unit area. They are, however, rather coarse and for that reason are avoided by the cattle during the latter part of the season. These two sages are therefore somewhat favored by light grazing. However, they do not seem to be able to take advantage of their strengthened condition, as *A. frigida* does in the case of heavy grazing. The latter species bears much the same relation to grazing in this area that snakeweed does to grazing in the Southwest.[23]

[22] This fact has been observed by Dr. H. L. Shantz in other parts of the Great Plains.

[23] Wooton, E. O. Factors affecting range management in New Mexico. U. S. Dept. Agr. Bul. 211, 39 pp., 3 figs., 9 pls. 1915.

Here on the prairie under light or moderate grazing the "weeds" (species other than the grasses and sedges) bear much the same relation to the intensity of grazing as they do in the bluegrass pastures of the South [24] except that they do not crowd out the more valuable species. It is therefore better to follow a system of grazing that will keep the weeds down and at the same time not allow any of them an opportunity to become noxious because of overgrazing. The 50-acre pasture so far has been able to do this, but the gains per head of the cattle have been somewhat reduced, as the pasture becomes very short toward the close of the season. The rotation pasture is able to accomplish the same results on a slightly reduced acreage and at the same time produce a higher gain per head.

CLIPPED QUADRATS.

The clipped quadrats were established in 1917. The vegetation is cut, or clipped, close to the ground with a pair of roaching shears. It is clipped uniformly closer than it would be grazed by cattle, but care is taken not to destroy the plant crowns. This method of quantitative determination was adopted to secure data on the period of most active growth of the different species and to determine the effect on subsequent growth of frequent removal of the vegetation.

Clippings have been made after 10, 20, 30, and 40 day periods, and also at the end of the season (annual). In 1919 a set of quadrats was added to include the biennial removal of the vegetation. During the same year was added a series of clipped quadrats which are cut in relation to the deferred and rotation system of grazing. The data from these are not included, as the quadrats are not old enough to be of more than minor significance. Duplicate square-meter quadrats were used. The arrangement of the quadrats and their appearance at the close of the grazing season in 1919 are shown in Plate VIII, Figure 2. The quadrats are located in the isolation transect of the 100-acre pasture and are therefore not disturbed by grazing.

It is recognized that there are individual differences between the quadrats. However, they are not great enough to overcome the effects of different intensities of clipping or to obviate the original conception of this method of analysis. The quadrats were clipped for the first time in June, 1917. The vegetation was removed from all quadrats on the same date. The vegetation on them had not been disturbed since 1915 and was only lightly grazed during that season. The total vegetation from each quadrat was weighed (in grams) both green and after becoming air dry. The weights from all quadrats ranged from 235 to 263 grams green and from 168 to 186 grams dry. This included all old growth along with that of the current year. The subsequent clippings have been divided, as shown in Table 9, into the individual dominant species and into other important groups at the time of cutting and weighed both green and dry. Pertinent notes were made of the stage and quantity of growth of all species.

The periods for clipping are now fixed, so that May 1 is considered the date from which all periods start each season. For example, the first clipping is made on May 10 for the 10-day periods, May

[24] Carrier, Lyman, and Oakley, R. A. The management of bluegrass pastures. Va. Agr. Exp. Sta. Bul. 204, 18 pp., 8 col. figs. 1914.

20 for the 20-day periods, etc. The "annual" is fixed at September 1, as there is very little growth after that date. In no season since these quadrats were started have the 10, 20, and 30 day quadrats made enough growth to afford vegetation for clipping at all possible periods. This has been largely because of drought.

Figure 10 shows in graphic form the periods of growth for the different species and groups. The 30-day period was selected for this study, as it represents each of the four months of the season and also corresponds to the weighing dates of the cattle. Bouteloua presents the most uniform line, showing that this species produces a

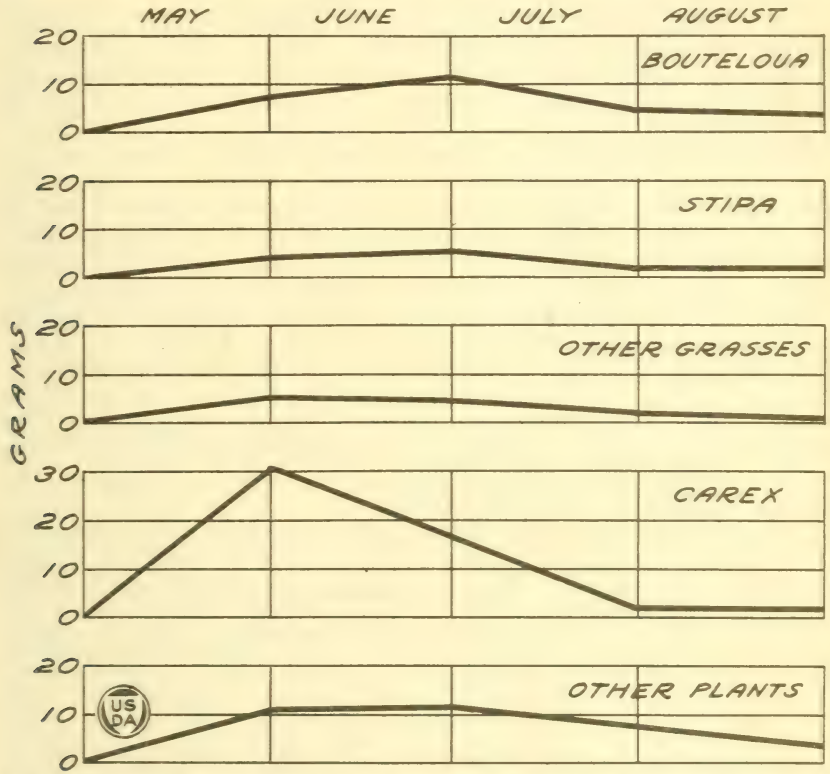

FIG. 10.—Diagram showing the average quantity of vegetation produced by different species and groups of plants at the end of 30-day periods for the period from 1917 to 1921, inclusive. The lines represent the green weight of the vegetation in grams per square-meter quadrant.

fairly uniform growth throughout the season. This is one of the reasons why it is such a valuable grass for grazing. Both Stipa and other grasses also produce fairly uniform lines, but their production is very light toward the close of the season. In the case of the two species of Carex there is a pronounced abundant early growth. *C. filifolia* is one of the earliest plants to mature. It sheds its seeds usually late in May and does not make much growth after that time. *C. heliophila* is not quite as early in maturing and makes more growth later in the season. The two species are shown together, but beginning in 1919 they were separated for the above reasons. In the

case of the "other plants," which include all other species, the curve is fairly uniform for the season. The diagram plainly shows that the period of most active growth, and therefore greatest production of the vegetation as a whole, is during May and June. This period corresponds to the period of the largest gains of the cattle.

In Table 9 are presented the average weights (in grams) for the different intensities of clipping. It will be noted that the totals for the 10-day and 20-day quadrats average very close to each other. This will also be observed for the 30-day and 40-day quadrats. Therefore, it would be possible to drop one of each pair and still retain practically the full value of the data.

The annual quadrats have a lesser total green weight than some of the others but a higher dry weight. This is to be expected, as many of the species are practically dry when cut. Bouteloua and the two species of Carex have produced lesser quantities in the annual quadrats than in any of the others. This may be accounted for in large part because of actual loss through drying. Since the two species of Carex mature early, they are much overripe by September, and part of the stems and leaves is lost by being blown away or dropping to the ground. This fact is only partially true for Bouteloua. The tips of the leaves dry up and may break off, but they are usually green below at this time. It has been noted from observation, and the clipping data confirm it, that Bouteloua is the one species that is benefited by frequent grazing or by clipping. This does not mean that it is impossible to injure this grass by overgrazing, but that it will permit severe grazing longer than any other species and that its growth is stimulated by moderate grazing. The same is true to a lesser degree for the two species of Carex. In the 10-day quadrats practically all that is now left are Bouteloua and Carex, and they have been weakened.

Table 9 shows that Stipa runs low in all quadrats up to the annual ones. From the data and observations of the biennial quadrats as compared with the ones cut annually there are indications that this species is weakened by even the annual cutting. However, as will be noted in Table 9, it is still producing fairly high in the annual quadrats. Stipa has disappeared from the different quadrats in direct relation to their frequency of clipping. The quantity produced was less than before in 1919 in the 10-day and 20-day quadrats, was practically nothing in 1920, and in 1921 there was none in the 10-day and only a trace in the 20-day quadrats. The 30-day quadrats in 1919 produced over 19 grams dry weight; in 1920, 0.65 gram; and a trace in 1921. The monthly removal of the vegetation by clipping and the weakening effect of it have been observed elsewhere.[25] In the 40-day quadrats the quantity was greatly reduced in 1920 and 1921, but they are still producing a light growth. The clipped quadrats show clearly and support the general observation that *Stipa comata* is more susceptible to a reduction or complete extinction by intense clipping or grazing than any other important species at this point. As previously noted, this species has been greatly reduced by severe grazing in the 30-acre pasture. Hardly a stalk of this grass has been allowed to mature normally in the 30-acre or the 50-acre pasture since 1916. The closed units of the isola-

[25] Sampson, Arthur W. Range improvement by deferred and rotation grazing. U. S. Dept. Agr. Bul. 34, 16 pp., 5 pls. 1913.

tion transect in the 30-acre pasture show that Stipa is becoming increasingly slower in producing seed stalks after protection from the hard grazing. This point was brought out in the past two years, and it is not yet clear how long it will take for this grass to reach a stage of normal seed production after it has been subjected to severe continuous grazing.

TABLE 9.—*Average quantity of vegetation produced annually by different species and groups of plants on the quadrats clipped at different intervals, in the 5-year period from 1917 to 1921, inclusive.*

Species or group.	Weight of vegetation per square-meter quadrat clipped at stated intervals (grams).[1]									
	10 days.		20 days.		30 days.		40 days.		Annual.	
	Green.	Dry.	Green.	Dry.	Green.	Dry.	Green.	Dry.	Green.	Dry.
Bouteloua gracilis	25.9	14.9	24.6	14.7	27.4	16.7	23.1	15.4	14.9	12.7
Stipa comata	5.3	3.1	6.8	4.2	13.1	8.0	12.8	8.0	35.8	29.8
Bouteloua gracilis and Stipa comata	31.2	18.0	31.4	18.9	40.7	24.7	35.9	23.4	50.7	42.5
Other grasses	8.8	4.4	8.1	4.4	11.9	6.6	14.0	7.8	6.4	5.0
Total, all grasses	40.0	22.4	39.5	23.3	52.6	31.3	49.9	31.2	57.1	47.5
Carex filifolia and Carex heliophila [2]	34.2	17.1	40.8	21.1	51.6	26.9	45.2	25.2	19.2	16.6
Other plants	31.1	9.9	29.8	9.0	32.6	11.1	47.5	16.5	44.6	22.2
Total, all species	105.3	49.4	110.1	53.4	136.6	69.3	142.6	72.9	120.9	86.3

[1] Grams per quadrat can be converted to pounds per acre by multiplying by the factor 8.922.
[2] These have been separated since and including 1919.

The "other grasses" of Table 9 show an apparent reduction in the annual quadrats. A grass that makes up a large percentage of these is *Koeleria cristata* (prairie June-grass). This species is the earliest grass to mature on the prairie. It is usually mature and starts to dry up before the end of June. It, however, makes some secondary growth in the fall. The grasses of this group that appear in the quadrats in their order of abundance are *Koeleria cristata*, *Aristida longiseta*, *Muhlenbergia cuspidata*, and *Agropyron smithii*.

The "other plants" shown in Table 9 are composed of species that appear in the quadrats that do not belong in any other division. The most abundant and important ones are *Artemisia gnaphalodes*, *A. dracunculoides*, *A. frigida*, *Solidago pulcherrima*, and *Psoralea argophylla*. *Artemisia gnaphalodes* makes more rapid and frequent recovery from clipping than the other species, and *Psoralea* the least. When *Psoralea* is cut once or twice early in the season it does not usually make much more growth that year. The "other plants" contain the highest percentage of water, as may be observed from the weights obtained.

There is nothing of particular significance in Table 9 in regard to the yield of "other plants." There are indications that the quantity has been reduced in those quadrats that are frequently clipped. This point is confirmed by observation and by the yearly data. It will be noted that the dry weight for "other plants" is much greater in the annual quadrats than in any of the others. This is true for two reasons: (1) Because the plants cut during the early part of the

season contain a high percentage of water and (2) because of the greater growth of the plants during the entire season.

The clipped quadrats have clearly answered the questions in regard to the period of most active growth and the effects of frequency of removal of the vegetation upon the various species. In addition, they furnish a basis from which to estimate the total quantity of vegetation annually produced.

PHOTOGRAPHS.

Photographs have been taken regularly in connection with the grazing experiment each year, beginning with 1915. The same views have been taken each year, so that certain photographs are directly comparable for a series of years. One set that has been taken in each pasture shows a general view of the quadrat area (an area 4 meters square in which the mapped quadrat is located) and a closer view of the quadrat that is mapped in detail. Starting in 1919, two sets of photographs giving a general view of the quadrat area have been taken each season. One set is taken about midsummer or early in July, the other at or near the close of the grazing season. The early set was added after the *Artemisia frigida* began to be conspicuous in the 30-acre pasture. This set of photographs shows the general condition of all pastures at the time when the vegetation is producing its maximum growth.

Photographs are of unusual value in connection with studies of this nature, as they bring out points and illustrate features that do not lend themselves readily to description or measurement. Photographs also produce a permanent record that can not be obtained in any other manner or as quickly.

GENERAL FIELD NOTES.

General field notes have been made regarding the native vegetation, beginning with the year 1915. Phenological dates are recorded for 27 different species of plants that are common on the prairie. These notes show that the prairie during the period from 1915 to 1921, inclusive, has turned green as early as April 15 and as late as May 20; it has started to show signs of "drying up" as early as June 15 and as late as August 15.

The points of main interest and importance in relation to the production of forage for grazing are (1) the time of starting spring growth and (2) the period of maximum growth. The problems of pasture management depend largely upon the time (1) of flowerstalk production, (2) fruiting, and (3) seed maturity.

The data in Table 10 are presented to show the periods of growth of the more important plant species. The dates in each case are the earliest and the latest that have been recorded.

It will be noted that there is considerable variation in the time the plants start their annual spring growth. This is largely determined by the season.

The field notes furnish a means of ready reference in regard to the periods of growth and development of the different plant species that can not be obtained as clearly in any other way.

TABLE 10.—*Periods of time when the most important plant species start their spring growth and mature their seed.*

Species.	Start of spring growth.	Period of seed maturity.
Bouteloua gracilis	Apr. 15 to May 15	August to Sept. 15.
Stipa comata	Apr. 1 to May 1	June 25 to July 10.
Koeleria cristata	Apr. 1 to Apr. 25	June 20 to June 30.
Carex filifolia	Apr. 1 to Apr. 20	May 20 to June 1.
Carex heliophila	....do	May 25 to June 10.
Artemisia frigida	Mar. 25 to May 1	Sept. 10 to Oct. 1.

OTHER STUDIES BEARING UPON THE EXPERIMENT.

MOWING EXPERIMENT.

This phase of the studies bearing upon the grazing experiment was started for two reasons: (1) To determine the quantity of hay annually produced and (2) to determine the effects upon total production of annual and biennial mowing. The mowing experiment was not begun until 1919, although plans had been completed for it previous to that time. Figure 11 shows the plan and arrangement of the units for mowing. The units in the center are mowed annually and those on either side in alternate years. They are 1 acre in size, and the hay from each is weighed separately. In 1919 the 9 acres were mowed and weighed. Some of the units had not been cut since 1915, while those on the east side were mowed in 1918. The yields from the different units are presented in Table 11. While there has been only one year, 1921, that the biennial units have been mowed as such, the yield is striking. The same relative difference is also true for the clipped quadrats which are cut annually and biennially and yielded at the rate of 799 and 1,664 pounds per acre, respectively. The old growth of 1920 made up about 35 per cent of the total weight. The increased yield, therefore, is not entirely the accumulated growth of the previous year, but is partly caused by the increased vigor and consequent greater growth of the vegetation of the current season.

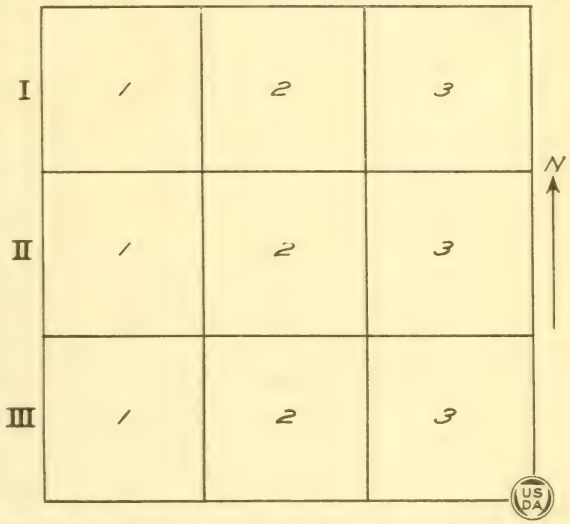

FIG. 11.—Diagram showing the plan of the mowing experiment (area, 9 acres): I, Mowed in odd years; II, mowed every year; III, mowed in even years.

The hay from the units mowed in alternate years was of poorer quality than that from those cut annually. This was because the

weeds in the biennial units were coarser and because of the accumulated growth of 1920, which made the hay "dusty." Each of these factors reduces the feeding value of the hay. There is also more waste in feeding the hay from the biennial units, but perhaps not enough to overcome the difference in yield.

TABLE 11.—*Yields of native hay for the years 1919 to 1921, inclusive.*

[Series I is mowed in odd years, Series II each year, and Series III in the even years.]

Year mowed.	Acre units.	Yield of hay per acre (pounds).			
		Series.			Average.
		I.	II.	III.	
1919	[1] 1	726	855	519	700
	[2] 2	560	492	697	583
	[3] 3	426	413	592	477
Average		570.7	586.7	602.7	586.7
1920	1		287	210	
	2		229	210	
	3		199	242	
Average			238.3	220.7	
1921	1	548	258		
	2	628	330		
	3	655	335		
Average		610.3	307.7		

[1] Not mowed since 1915. [2] Part mowed in 1916 and 1917. [3] Mowed in 1918.

The mowed units bear a direct relation to the grazing experiment, as they at once supply data upon which to base an estimate of the extent of the feed annually available for grazing. The units also bear a direct relation to the clipped quadrats. The quantity of feed the cattle obtain by grazing is between that of the yields of the mowed units and the clipped quadrats. The cattle get feed by grazing that is not recovered by a mowing machine, but they do not graze as closely as the vegetation is removed in the clipped quadrats.

Blue grama grass and the two species of Carex enter but slightly into the hay, as during most seasons they are too short to be cut with a mowing machine.

FIELD GERMINATION TESTS.

Field germination tests have been made with more than 30 species of native grasses. The seeds were collected during 1916 and 1917 and were planted in the grass nursery in the spring of 1918. Seeds of some of the more common species have been collected and planted since that time. In no case has any one of the highly important grazing grasses shown a high degree of germination. *Bouteloua gracilis* is very low in vitality and produced only two or three plants from several hundred seeds sown. The same is true for *Stipa comata*. However, another species of Stipa (*S. viridula*), which is not common on the prairie, has a germination equal to that of the ordinary field crops. *Koeleria cristata* also has shown a very low germination. Seasons more favorable to the growth and ma-

turity of the grasses may show an improvement in germination, but from all available data it appears that the seeds of many of the important grasses have a low degree of vitality. These grasses are able to maintain themselves under normal conditions by their strong vegetative growth and in favorable seasons by the production of a large number of seeds, a few of which will grow and become established.

SEEDING EXPERIMENTS IN NATIVE SOD.

A number of attempts have been made each year to establish some of the cultivated forage crops in the native sod without breaking it. Trials have been made with brome-grass, alfalfa, sweet clover, and the wheat-grasses both with and without disking the sod. These trials have furnished but slight encouragement for such a practice. The dry seasons may have prevented securing a stand, as practically every year some seedlings start growth but dry up before the end of the season. The native sod is already supporting all the vegetation possible, and unless this is destroyed by breaking there is but slight chance of anything else being able to compete with it.

SOIL MOISTURE.

Soil-moisture determinations have been made in each of the continuously grazed pastures every year since the experiment started in 1916. The soil samples have been taken around the quadrat area in each case.

The first foot of soil has been filled with water at the beginning of the season each year, but in all pastures has been reduced to the minimum before the end of the season every year since 1917.

The second foot of soil was filled with water at the beginning of the seasons of 1916 and 1917. It has not been completely filled since that time during any part of any season.

The moisture in the third foot has decreased from about 20 per cent in 1916 to 11 per cent in 1921 in all pastures. The same general reduction has held true for the fourth foot. The reduction of moisture in the fifth and sixth feet did not become pronounced until 1919. This was also true for wheat plats in the rotations at the station.

The soil-moisture data show very clearly that there has been a reduction of moisture in the sixth foot of all pastures except the 30-acre pasture. In this pasture there has been but little change in moisture content in the sixth foot since the middle of the season of 1919. This has no doubt been caused by the intense grazing. All of the plants except *Artemisia frigida* are eaten before they have a chance to use moisture to a depth of 6 feet. The available moisture at this depth has not been required by *A. frigida* because of the reduction of competition with other species for moisture above the sixth foot.

PALATABILITY OF THE VEGETATION.

The grasses annually produce from 45 to 55 per cent of the dry weight of all species. This fact is one of the highest significance, since it indicates an area of high grazing value for cattle.

In general, cattle and horses use a grass range to better advantage than sheep. Sheep relish tender green foliage and the grains of many grasses, but they eat

sparingly of coarse or dry grass foliage. Cattle consume a much larger proportion of the coarse grass forage. Horses, even more than cattle, prefer grass to weeds and browse.[26]

It is not only a matter of interest, but one of importance to know what a steer likes or dislikes while he is grazing native vegetation. It has often been said that "a steer will eat anything he is obliged to." This is literally true, but he always shows a marked preference for certain species of plants over others.[27] This preference may to a large extent determine the best system of grazing in order to make the maximum utilization of the vegetation and avoid overgrazing.

The palatability for cattle of the grass species is high. It is estimated that the grasses of this section of the Great Plains are 90 per cent palatable. This means that there are but few grasses that cattle will not eat readily and at any time without being forced to do so because of the shortage of forage.

The following grasses enter more or less into the feed of grazing animals and are listed in their order of palatability: *Bouteloua gracilis* (blue grama), *Andropogon furcatus* (big bluestem), *Stipa comata* (western needle grass), *Koeleria cristata* (prairie June-grass), *Bouteloua curtipendula* (tall grama), *Andropogon scoparius* (little bluestem), *Muhlenbergia cuspidata* (prairie rush-grass), *Calamovilfa longifolia* (big sand-grass), *Stipa spartea* (porcupine grass), and *Aristida longiseta* (wire-grass or triple awn-grass). Further discussion of most of the above grasses and their chemical composition may be found in other publications of the department.[28]

Blue grama is placed at the head of the list, because it is the one grass that cattle do not hesitate to graze at any time during the season after it has reached the grazing stage early in June. In the early season, while it is green and fresh, cattle eat it readily. In the autumn, after it has matured, the cattle will nose down through other species to obtain blue grama. This grass, which passes under the names of "grama" and "buffalo grass," has a better reputation for grazing in the Great Plains than any other single species of grass unless it is the true buffalo grass (*Bulbilis dactyloides*), with which it is often confused in the popular mind, which, however, occurs sparingly in this part of the Great Plains.[29]

Big bluestem is placed second in palatability because it is grazed with extreme relish by the cattle during the early part of the season. This grass is not an upland species, but thrives best along river bottoms; it occurs, however, in several small ravines in the pastures. This is the first grass that the cattle "clean up" early. They graze it close at once and will often pick over an area that has already been closely grazed while there is abundant feed in other parts of the pasture. This has been observed each year since the experiment started. However, in the fall when they have a chance to eat this grass on an area that has not been grazed that season, they will not graze it until other feed becomes scarce. There is a good reason for this seasonal choice. In the spring big bluestem is

[26] Jardine, James T., and Anderson, Mark. Range management on the National Forests. U. S. Dept. Agr. Bul. 790, 98 pp., 4 figs., 32 pls. 1919.

[27] Thornber, J. J. The grazing ranges of Arizona. Ariz. Agr. Exp. Sta. Bul. 65, 360 pp., 6 figs., 12 pls. 1910.

[28] Griffiths, David, George L. Bidwell, and Charles E. Goodrich. Native pasture grasses of the United States. U. S. Dept. Agr. Bul. 201, 52 pp., 9 pls. 1915.

[29] Sarvis, J. T. Composition and density of the native vegetation in the vicinity of the Northern Great Plains Field Station. *In* Jour. Agr. Research, v. 19, pp. 63–72, 2 figs., pls. 12–14. 1920.

tender, juicy, and sweet, and it also has a very pleasant odor, but by fall it has become harsh and woody and lost its sweetness and is then passed by for something better.

Western needle grass is eaten readily by cattle early in the season up to the time the needles form and become sharp. For a period of two to three weeks it is avoided by stock, but when the needles drop it is again taken well, even after it has become dried. This grass starts growth early in the spring, before most other grasses. It also grows late in the fall and produces some green feed after most of the other grasses have ceased growth for the season.

Prairie June-grass is one of the earliest grasses to start growth in the spring and is the earliest one to reach maturity. It furnishes luxuriant green feed during late May and early June which is readily eaten by the cattle. It soon dries up, however, and the foliage is almost entirely lost to cattle in areas that are not grazed early in the season.

Tall grama grass produces feed early in the season that is readily eaten by stock. It makes a much taller growth than the blue grama. In the early part of the season the foliage is tender and sweet, but later the stems become tough and woody.

Little bluestem seems to be more or less avoided by cattle. This is partly because the old stems are stiff and protect the young growth in the spring. On areas where this grass has been grazed down by cattle they do not hesitate about grazing the same area the next season while the growth is tender.

The other grasses are of minor value for grazing, from the standpoint of their palatability. They are all somewhat tough and are therefore avoided. Wire-grass (Aristida) is the last grass that the cattle will take when forced to graze a short range. Bunches of this grass are often found scattered over the pasture when everything else around them has been eaten. When the cattle start to eat the bunches of this grass it is a good indication that they are out of other feed. The awns of this grass are very sharp, and they do not readily drop, as in the case of species of Stipa.

The two species of Carex are high in palatability for cattle early in the season and are estimated at 100 per cent palatable until late June. As the summer advances their palatability decreases to practically nothing for *Carex filifolia* (nigger wool) by the close of the season. This species becomes dry and tough with age. *C. heliophila* (western prairie sedge)[30] remains palatable longer and is not greatly avoided by the cattle at the close of the season.

The palatability for cattle of the other plants is low; it is estimated at not more than 30 to 40 per cent. It is true that the cattle eat most of these plants when other feed is scarce, but of their own choice they eat only a small percentage. The plant that they avoid most of all is *Artemisia frigida.* They will not eat this at any time until they are forced to do so. As already mentioned, in the 30-acre pasture, where this plant has become coarser than in the other pastures, the cattle reject it until the last and lose weight while a considerable portion of it is still untouched. None of the other species are particularly avoided. The low palatability of these

[30] This name has been applied locally to this species, as the plant is very common, and it is often desirable to refer to it under a popular name.

plants generally reduces the value of the total vegetation of this region. It is estimated that the palatability for cattle of the vegetation as a whole is approximately 75 per cent, but that 95 per cent of it will be eaten when cattle are forced to graze a short range.

CAUSES OF THE DETERIORATION OF NATIVE PASTURES BY GRAZING WITH CATTLE.

The main causes of the deterioration of native pastures when grazed by cattle are (1) too early grazing in the spring, (2) continuous grazing, and (3) overgrazing.

While it is the universal practice to turn the cattle into the pasture as soon as the snow is off the ground in the spring, this fact can not obviate the injury to the vegetation. This injury is caused by the trampling of the cattle in the wet soil and by their picking off the young vegetation as soon as it starts growth. Grazing in the northern Great Plains should not begin before May 1 to May 15. By that time the vegetation has usually made enough growth so that it can keep ahead of the grazing. The grazing experiment at Mandan has never been started before May 15. There are conditions under which cattle may be turned on the native pastures early in the spring without serious results except the damage done by trampling. These conditions are found in pastures that are annually undergrazed and therefore have sufficient old growth to maintain the cattle for a short period.

While continuous grazing at the proper rate may not directly injure the vegetation as a whole, some species are likely to be weakened because of overgrazing, while others may become so coarse that they are avoided because of undergrazing. Cattle will eat certain species in preference to others each season, which will result in severe injury to the preferred species. This point is well illustrated in the case of big bluestem in the 100-acre pasture. A small area of this grass occurs in a depression. Each spring the cattle have grazed this grass and kept it short, until at the present time the area has become infested with weeds and its grazing value reduced.

Overgrazing is brought about by trying to feed too many cattle upon too few acres. This is the most common cause of native-pasture deterioration. If continuous overgrazing is practiced long enough it will eventually mean the abandonment of the land for pasture purposes. The cumulative effect of overgrazing is brought about by the continual removal of the vegetation year after year without affording it an opportunity to produce a crop normally. This condition will sooner or later mean the death of most of the valuable grazing plants.

The system of deferred and rotation grazing is designed to reduce to a minimum the causes of deterioration of native pastures. This is effected by allowing each division of the pasture to bear its burden of early-spring grazing equally with other divisions and also allows each division to share equally the benefits of normal growth and grazing after the maturity of the vegetation.

The following citations have a direct bearing upon the above points:

The permanent welfare of the livestock business itself demands that the grazing seasons should not begin too early, because the maintenance of the maximum permanent carrying capacity of the range is identical with the permanent welfare of the communities or individuals depending upon the range.

Premature grazing was undoubtedly one of the foremost causes of the deterioration of range lands prior to regulated grazing; and the fixing of grazing periods on the lands within the National Forests has had as much to do with range improvement as reductions in number of stock, if not more.[31]

(1) Removal of the herbage year after year during the early part of the growing season weakens the plants, delays the resumption of growth, advances the time of maturity, and decreases the seed production and the fertility of the seed.

(2) Under the practice of yearlong or seasonlong grazing both the growth of the plants and seed production are seriously interfered with. A range so used when stocked to its full capacity finally becomes denuded.

(3) Grazing after seed maturity in no way interferes with flower-stalk production. As much fertile seed is produced as where the vegetation is protected from grazing during the whole of the year.

(4) Deferred grazing [grazing after seed maturity] insures the planting of the seed crop and the permanent establishment of seedling plants without sacrificing the season's forage or establishing a fire hazard.

(5) Deferred grazing can be applied wherever the vegetation remains palatable after seed maturity and produces a seed crop, provided ample water facilities for stock exist or may be developed.

(6) Yearlong protection [against grazing] of the range favors plant growth and seed production but does not insure the planting of the seed. Moreover, it is impracticable, because of the entire loss of the forage crop and the fire danger resulting from the accumulation of inflammable material.[32]

GRAZING CAPACITY BASED UPON THE NATIVE VEGETATION.[33]

The investigations in connection with this experiment are by no means completed. It is recognized that further experimentation may intensify or modify the results already obtained. The results so far secured, however, have an important bearing upon the value of different systems and intensities of grazing and the effects upon the native vegetation. It is not expected that the continuance of the severe grazing in the smaller pastures will afford them an opportunity to recuperate enough to regain their maximum grazing capacity even under the most favorable seasonal conditions.

It might appear that the grazing capacity of the vegetation, as measured by the effects of different intensities of grazing, is antagonistic to the most economical gains of the cattle and to efficient range management. However true this might appear from the earlier results of the grazing experiment, the two must eventually coincide, since the cattle are entirely dependent upon the native vegetation for their food supply while grazing. Any system or intensity of grazing that will allow the plants to continue their maximum seasonal production will be reflected in the gains of the cattle. The most efficient system of grazing may or may not be the one that produces the most immediate profit, but it will produce the most profit

[31] Jardine, James T., and Anderson, Mark. Range management on the national forests. U. S. Dept. Agr. Bul. 790, 98 pp., 4 figs., 32 pls. 1919.

[32] Sampson, Arthur W. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. *In* Jour. Agr. Research, v. 3, pp. 93–148, 6 figs., pls. 12–23. 1914.

[33] The term "grazing capacity" has been used in this publication in preference to "carrying capacity," as it more nearly expresses the manner of forage utilization. This term has also been applied in other publications. See Jardine, James T., and Anderson, Mark. Range management on the national forests, U. S. Dept. Agr. Bul. 790, 98 pp., 4 figs., 32 pls., 1919; and Smith, Jared G., Experiments in range improvement, U. S. Dept. Agr., Div. Agros. Circ. 8, 5 pp., 1 fig., 1898.

over a series of years. The same is true as regards the gain per acre produced.

THE 100-ACRE PASTURE.

The 100-acre pasture, which is grazed at the rate of one 2-year-old steer to 10 acres, has produced an abundance of feed each season that the experiment has been in progress. It has not been injured by overgrazing but has slightly deteriorated because of undergrazing, but not to the same degree or in the same way that other pastures have deteriorated from overgrazing. This deterioration is shown by the increased coarseness of the "weeds" and the accumulation of old vegetation, which the cattle avoid as long as possible. There has been enough forage produced in this pasture at all times to allow the cattle to make nearly the maximum gains per head. The size of the pasture, however, has resulted in low gains per acre. An area of 10 acres is more land than is required to carry a steer for five months during the summer season under a system of continuous grazing. Such an underutilization of land is not beneficial to the native vegetation or to the cattle grazing upon it.

THE 70-ACRE PASTURE.

The 70-acre pasture, which is grazed at the rate of one 2-year-old steer to 7 acres, has produced abundant feed to meet the requirements of the cattle and make the maximum gains per head. The number of acres has kept it from producing a high gain per acre, but its gains have been higher than in the 100-acre pasture. The pasture has not been overgrazed nor has it shown the same effect of undergrazing that is apparent in the larger pasture. An area of 7 acres approximately is required to graze a steer for five months during the summer season under a system of continuous grazing. In good years there will be an excess of forage, and in poor years the forage produced will be sufficient to feed the usual number of steers without overgrazing. In order to insure a pasture from overgrazing under this system it is necessary that from 15 to 25 per cent of the vegetation remain standing at the close of the season. Whenever the vegetation under a system of continuous grazing falls below this, the pasture is on the danger line of destructive overgrazing. It should not be overlooked that this pasture has produced remarkably well.

THE 50-ACRE PASTURE.

The 50-acre pasture is grazed at the rate of one 2-year-old steer to 5 acres. It has not yielded enough forage to carry the cattle through the season and produce maximum gains per head. The gain per acre has been greater than that of the two larger pastures because of the reduced acreage. During the first two years of the experiment there was feed enough to enable the cattle to make gains equal to those in the 70-acre pasture. Since that time the gains have decreased because of feed shortage. During only one year has it been necessary to move the cattle to another pasture before the close of the season; but they have lost weight toward the end of the season every year since 1917. An area of 5 acres is not enough to insure forage sufficient to carry a steer for five months during the summer without

loss in weight toward the close of the season. The vegetation has not been severely damaged by the heavy grazing to date, but it would require a period of rest or a different system of grazing to bring it back to a state of maximum production. In order for a pasture of this size to produce enough feed to graze cattle for five months and produce normal gains, it would be necessary for it to yield a maximum crop of forage each year.

THE 30-ACRE PASTURE.

The 30-acre pasture is grazed at the rate of one 2-year-old steer to 3 acres. It has not produced feed enough to carry the cattle and produce normal gains for more than an average of two months each season. The seasonal gain per head has been less than for any other pasture, but the gain per acre has been the highest produced, because of the reduced acreage. Early in the season, or during the time when the vegetation is making its maximum growth, the cattle make gains equal to those in the other pastures. This pasture has been overgrazed, which is best shown by the increase of *Artemisia frigida;* it is not large enough to produce sufficient feed to graze the cattle for five months even during a season of maximum crop production.

The increase in the number of plants of *A. frigida* on overgrazed pastures is not confined to the area included in the grazing experiment. Many native pastures in the vicinity of Mandan are so badly infested with a heavy growth of this sage that they have been practically abandoned. The results obtained in the 30-acre pasture indicate that it does not take a pasture many years to reach this condition under continuous severe grazing. Plate IX shows an abundance of this plant in a pasture adjoining the station, which had been heavily grazed for a number of years.

While the 30-acre pasture has been severely injured by overgrazing, no effort as yet has been made to restore it to higher production. It is probable that when this is done it will be by a system of deferred and rotation grazing, which may be aided by some mechanical means.

The results obtained on this small pasture are remarkable in showing that the cattle are able to maintain themselves and make some gain as long as they do. They also clearly bring out a point not generally recognized, that cattle on a short pasture may appear to be doing well when, in fact, they are only maintaining their weight.

THE 70-ACRE DEFERRED AND ROTATION PASTURE.

For the first two years the deferred and rotation pasture was grazed at the rate of one 2-year-old steer to 7 acres. During 1921 the rate was one steer to 4.12 acres. At the higher rate of grazing it produced feed enough to make gains per head greater than the small pastures but less than the larger pastures and at the same time showed the greatest total gain per acre. The utilization of the vegetation has been greater for the gains made than in any other pasture, with a minimum injury to the vegetation. This system of grazing is to be preferred to that of continuous grazing, since a greater total gain can be produced on less acres.

The cost of fencing a deferred and rotation pasture will be more than to inclose one of the same size for continuous grazing, but 50

per cent more cattle can be grazed on the same area. This will in a short time more than pay for the extra cost of fences. This system of grazing could be readily applied on many farms or ranches. It often happens that the land for pastures is divided by roads, so that it is necessary to operate independent pastures. When such a condition exists the system of deferred and rotation grazing can be put in operation at once without additional cost.

SALIENT POINTS REVEALED BY THE GRAZING EXPERIMENT.

Of more than 250 species of plants at the Northern Great Plains Field Station, less than a dozen play a dominant rôle in grazing.

Bouteloua gracilis (blue grama grass) is the species least injured by heavy grazing and apparently is benefited by moderate to close grazing.

Stipa comata (western needle grass) is the species most injured by heavy grazing.

Artemisia frigida (pasture sage) is the best indicator of overgrazing, because cattle do not like it, and it is able to take advantage of the weakened condition of other plants and increase in number and size per unit area.

The range vegetation makes 75 per cent of its growth during May and June.

The total gains that can be made on native pastures in this area of the Great Plains have never been fully realized by stockmen or those interested in grazing problems.

In a grazing experiment it is equally important to know what is happening to the cattle and to the vegetation.

Cattle make their largest gains during the early season on green grass and not in the fall on mature grass. This is true as long as the quantity of feed early in the season is not a limiting factor.

Cattle grazing on a short range may appear to be doing well when, in fact, they are no more than maintaining their weight.

Grazing longer than four months has not increased the gains per head, but has resulted in a better "finish."

Under a system of continuous grazing it requires 7 acres to graze one 2-year-old steer for five months.

Between 4 and 5 acres will graze a 2-year-old steer for five months under a system of deferred and rotation grazing.

The highest gain per head of cattle is not correlated with the highest gain per acre.

The lowest gain per head made on the lowest acreage is correlated with the highest individual gain per acre, provided the cattle are not forced to remain on a short pasture for too long a period.

The measure of efficiency of a pasture or system of grazing is not determined by one factor but by several of equal importance.

CONCLUSIONS AND SUMMARY.

The cooperative grazing experiment reported upon in this bulletin was established at the Northern Great Plains Field Station, near Mandan, N. Dak., in 1915. Its objects were to determine the grazing capacity of the native range and the effects of different systems and intensities of grazing upon the native vegetation.

The experiment is conducted with four pastures under a system of continuous grazing. These pastures vary in size from 100 to 30 acres. A pasture of 70 acres conducted under a system of deferred and rotation grazing was added in 1918.

The land used for the experiment is not materially different than other vast areas in western North Dakota. This land, however, is better than would ordinarily be used for grazing. It is well adapted for experimental purposes because of its uniformity.

Early seasonal precipitation exerts a greater influence upon the production of native forage than upon other crops.

The deferred and rotation system of grazing is designed to allow different divisions of the pasture to mature a crop normally before it is grazed. Under this arrangement a greater utilization of the vegetation is obtained with less injury to it than in any other pasture, and with the greatest total gain.

The grazing season for this experiment is five months during the summer. Winter grazing is not taken into consideration and is not recommended for this section except under very unusual conditions.

The cattle used in the experiment are 2-year-old grade steers. They are weighed individually at 30-day intervals throughout the season.

The cattle have made average gains per head ranging from 294 pounds in the 70-acre pasture to 180 pounds in the 30-acre pasture. A high gain per head does not produce the largest gain per acre. A gain per head higher than the small pastures but lower than the large pastures is produced on the deferred and rotation pasture. The total gain per acre in the rotation pasture has been higher than in any of the others since the number of cattle has been increased.

The quantity of the foliage cover annually removed by grazing varies on the average from 51 per cent in the 100-acre pasture to 98 per cent in the 30-acre pasture. In order to avoid injury to the vegetation under a system of continuous grazing, from 15 to 25 per cent of the foliage cover must remain on the pasture at the close of the grazing season. A greater utilization of it may be made under the system of deferred and rotation grazing.

The most efficient system of grazing is one that will insure sufficient forage during the entire season to produce the greatest total gain in weight with the least number of cattle on the minimum unit of land without permanent injury to the native vegetation. The requirements of this measure of grazing efficiency are most nearly fulfilled by the deferred and rotation system of grazing.

Botanical studies in connection with the grazing experiment are necessary in order to determine the effect of different systems and intensities of grazing upon the native vegetation.

The vegetation has a total basal cover of approximately 60 per cent. Of the basal cover 20 per cent is made up of *Bouteloua gracilis*, 10 per cent of *Stipa comata*, and 30 per cent of other vegetation.

The dominant species are *Bouteloua gracilis*, *Stipa comata*, *Carex filifolia*, and *C. heliophila*.

As the vegetation is the "climax" type, having the highest development, the grazing should be so adjusted as to maintain it without deterioration.

The mapped quadrats used in these experiments are of value in securing a permanent record of the composition of the

native vegetation. They also indicate the effects of grazing upon species that grow in mats or small bunches. From these maps it is clear that the quantity of *Stipa comata* has been reduced by the overgrazing in the 30-acre pasture.

The list quadrats used in these experiments are of great value in keeping a record of the number of plants of different species. These quadrats show that *Artemisia frigida* has increased in extent under the heavy grazing in the 30-acre pasture. The vigor of the individual plants of this species has been favored by the reduction of the competition of other species in the small pasture.

The clipped quadrats used in the experiment were designed to facilitate the study of the effects of frequent and infrequent removal of the vegetation upon its subsequent growth and also to determine the period of greatest growth. In the frequently clipped quadrats *Stipa comata* has disappeared, other species have been weakened, and the total production has been reduced. *Bouteloua gracilis* is the one species that appears to respond to frequent clippings better than any other species. The greatest growth of the vegetation occurs early in the season at the time the cattle make their greatest gains.

Photographs of the plants growing in the different pastures have been taken from the same points each year. These form permanent authentic records that can not be obtained in any other way.

Areas known as "isolation transects" were set aside in the 100-acre and 30-acre pastures and in one division of the rotation pasture. Units are annually closed to grazing on one side of the transect and opened to grazing on the other, while the central units are never grazed. The units that are annually closed to grazing in the 30-acre pasture contain about five times as many plants of *Artemisia frigida* as those that are never grazed. The plants of this species are also more vigorous in the units closed in 1920 and 1921 than in those closed previous to 1920.

General field notes are kept each year upon 27 different species of plants that are common on the prairie. These notes show that the prairie has turned green in the spring as early as April 15 and as late as May 20, while it has started to "dry up" as early as June 15.

A mowing experiment was undertaken to determine the effects of the annual and biennial removal of the vegetation upon the total production. The yields also furnish data from which the quantity of forage available for grazing may be determined.

Field germination tests show that the seeds of many of the most valuable range grasses are low in vitality.

Each year a number of trials have been made to grow cultivated forage plants sown in the native sod without breaking. The results show that it is almost impossible to get the plants to grow in a vegetation of such density.

Soil-moisture determinations show that the first foot of soil in all pastures is well filled with water at the beginning of each season. It was not until 1919 that the moisture of the sixth foot of soil was greatly reduced. The sixth foot of soil in the 30-acre pasture has not been reduced to the same degree as in the other pastures.

The grasses of this region make up about 50 per cent of the dry weight of all species of plants. It is estimated that 90 per cent of them are palatable and therefore afford excellent grazing for cattle.

Bouteloua gracilis and *Andropogon furcatus* are the most palatable grasses, while *Artemisia frigida* is the least palatable of all species of plants. Cattle do not like it and will not eat it unless forced to do so because of the shortage of other feed.

Native pastures deteriorate when grazed because of (1) too early grazing in the spring, (2) continuous grazing, and (3) overgrazing. All of these factors can be controlled.

The grazing capacity of the native vegetation of the area included in these experiments is shown by the results in the several pastures. The 100-acre pasture, grazed at the rate of one steer to 10 acres, is larger than is necessary to produce the maximum gains per head. This pasture is undergrazed. The 70-acre pasture, grazed at the rate of one steer to 7 acres, provides approximately the area of land required to produce the maximum gains per head under a system of continuous grazing. The 50-acre pasture, grazed at the rate of one steer to 5 acres, is not large enough to allow the cattle to make maximum gains per head. This pasture is overgrazed. The 30-acre pasture, grazed at the rate of one steer to 3 acres, is not large enough to carry the cattle for five months. This pasture is severely overgrazed. Under a system of deferred and rotation grazing the number of acres required per head is reduced to between 4 and 5. This acreage will provide enough feed to allow the cattle to make gains per head intermediate between those made in the 50-acre pasture and those made in the 70-acre and 100-acre pastures. This system allows the maximum utilization of the vegetation without the injury to it accompanying overgrazing.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

Secretary of Agriculture	HENRY C. WALLACE.
Assistant Secretary	C. W. PUGSLEY.
Director of Scientific Work	E. D. BALL.
Director of Regulatory Work	———.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	HENRY C. TAYLOR, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	WALTER G. CAMPBELL, *Acting Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. COTTRELL, *Director.*
Division of Accounts and Disbursements	A. ZAPPONE, *Chief.*
Division of Publications	EDWIN C. POWELL, *Acting Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
States Relations Service	A. C. TRUE, *Director.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration *Grain Future Trading Act Administration*	CHESTER MORRILL, *Assistant to the Secretary.*
Office of the Solicitor	R. W. WILLIAMS, *Solicitor.*

This bulletin is a contribution from

Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Office of Dry-Land Agriculture Investigations.	E. C. CHILCOTT, *Agriculturist in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

PURCHASER AGREES NOT TO RESELL OR DISTRIBUTE THIS COPY FOR PROFIT.—PUB. RES. 57, APPROVED MAY 11, 1922

▽